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THE JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY

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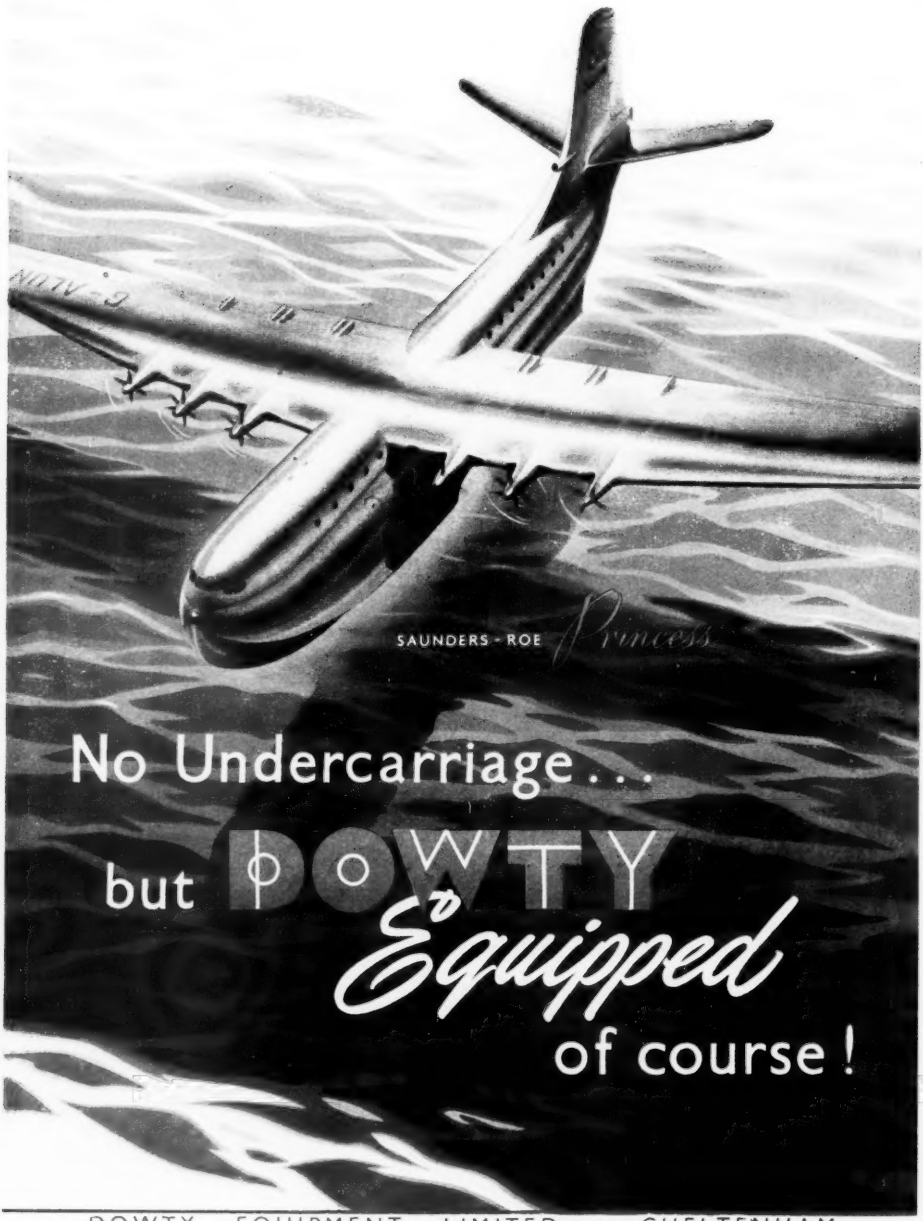


DOWTY EQUIPMENT LIMITED · CHELTENHAM

Secretary's News Letter

NOVEMBER 1952

AT the Council Meeting on 25th September approval was given for the founding of two new Branches, one at Henlow and the other at Merthyr Tydfil.

This now brings the total number of Branches in the United Kingdom to 23; this is a goodly number by any standard.

The inaugural meetings have not yet been held; I shall tell of these later.

In my last news letter I mentioned Mr. Nash of the Southern Africa Division. Since I last wrote I have received a visit from Mr. L. C. Williams of the Australian Division. The President and Council were very pleased to have the opportunity of welcoming both Mr. Nash and Mr. Williams to the Dinner after the British Commonwealth and Empire Lecture. For the first time a toast to the Divisions was made. I hope that this may be a customary feature of this Dinner. This will only be if overseas members inform me when they will be in this country, and so enable me to make the necessary arrangements.

I have said I am pleased to welcome overseas members; the Divisions also will be very pleased to have the opportunity of seeing members, making fleeting visits abroad. There is a genuine desire on their part for such meetings, and, if I am informed by members intending to visit the Commonwealth, I shall make arrangements for meetings with the Divisions. Too often in the past have I had to say, "if only I had known." A timely letter in the future will prevent the occurrence again of such a state of affairs.

Both the President and I attended the Annual Dinner of the Institution of Mechanical Engineers. This was held at the Dorchester on 16th October. The President of the Institution of Mechanical Engineers, Sir David Pye, is not unknown to us; he is a former Member of Council of the Society.

The Annual General Meeting of the Halton Branch was held on 11th October. The new Secretary of the Branch, F./O. E. S. Street, paid tribute to the work of the retiring Secretary, Mr. J. N. Angless. The President and Council are appreciative of the very great spare-time effort given by all the Branch Secretaries, for upon their enthusiasm rests the success of the Branch and much of the success of the Society itself. In going round the Branches I see at first hand the results of the work of the Secretaries, and I realise the thought for details which has been given to such good effort.

At the conclusion of the A.G.M. at Halton, due to the delay in the arrival of Mr. N. E. Rowe, I presented the Deane Memorial Trophy to Flight Sergeant Apprentice G. F. Poyser. This was the first presentation of this trophy, to be awarded annually for the best student paper.

After this we went for tea at the Canteen. It is some years since I tasted NAAFI tea but it still tastes the same, having the same old attributes of being sweet, wet and warm.

Tea was followed by a lecture by Sir Victor Goddard, Principal of Cranfield. Sir Victor was introduced by an apprentice, and the vote of thanks was proposed by yet another apprentice. This seemed to me to be rather a good idea. Perhaps other Branches might consider doing something of a similar kind.

During the month I have visited the Naval Engineering College at Manadon, and also Loughborough College. It is of much importance that engineering at the latter College has been given its freedom, and has now an entity entirely separate from the other functions of Loughborough. I'm sure we all wish them success.

For a second year Mr. J. Lankester Parker has been installed as the Master of the Guild of Air Pilots and Air Navigators of the British Empire. The ceremony was held in the Innholders Hall in College Street. This is a fine ceremony and the Guild must be congratulated on the procedure they have evolved.

The well-known American aviation historian Mr. E. Hildes-Heim, of Connecticut, called to see the Society's Cuthbert-Hodgson collection and he was, frankly, envious. He admitted that the Society's collection was second—to very few.

Mr. Grover Loening and Dr. J. C. Hunsaker paid all too fleeting a visit, but I'm told they were able to see some of their many friends.

Professor J. D. Scott, Professor in Pasture Management and Soil Cultivation at Pietermaritzburg, South Africa, called and discussed the question of fertilising by means of aircraft. Luckily I was able to give him one or two leads in his search for information.

A. M. Ballantyne

Secretary

NOTICES

CONTENTS OF THE NOVEMBER JOURNAL

Eighth British Commonwealth and Empire Lecture—Maintaining Airworthiness in Operation, R. E. Hardingham, O.B.E., F.R.Ae.S., M.S.L.A.E.

Fatigue Life of Wing Components for Civil Aircraft, Keri Williams, B.Sc., A.F.R.Ae.S.

Civil Aviation in the Second Elizabethan Era, G. N. Roberts, C.B.E., A.F.C.

Reviews. Additions to the Library.

An annual sum of £200 is available for premium awards for papers published in the Journal. These premium awards are usually 15 guineas each. Members and non-members of the Society are invited to submit papers on any aspect of aeronautics.

JOURNAL BINDING

Self-Binder Cases

Self-Binder cases of the "Easibind" type are available from the offices of the Society. These binders are for members who do not have their Journals permanently bound, or who wish to keep their Journals together during the year for binding later.

These cases will hold 12 Journals which are kept in place by means of flexible steel wires. Journals can be inserted or withdrawn easily without damage, so preserving the contents for permanent binding later. The Journals will open flat at any page.

The binder is strongly made in durable dark blue leather cloth on stiff board covers and has gold lettering on the spine. The year is not blocked on the spine but there is a panel on which members who wish to use the binder as a permanent case can put the date.

The cost is 11s. 6d. each including postage and packing for either the size to fit 1952 and previous Journals, or for the size to fit the Journal from January 1953 which will be increased in size. Orders and remittances should be sent direct to the Secretary at the offices of the Society and it is important to state whether the old size or new size is required.

Permanent Binding

There is no increase in the price of permanent binding of Journals. The prices are:—

1952 Volume (including packing and postage)	16s. 0d.
Previous Volumes (including packing and postage)	18s. 0d.

Journals, with a note of the name and address of the sender, should be sent direct to the Lewes Press, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the offices of the Society.

FIRST CHURCHILL GOLD MEDAL AWARD

The First Churchill Gold Medal of the Society of Engineers was presented to Air Commodore Sir Frank Whittle, *Fellow*, by the President of the Society, Mr. R. S. V. Hoare, on 6th October. The Medal is awarded every two years for some notable achievement in the engineering world.

COLONEL W. C. DEVEREUX

A Memorial Plaque to the late Colonel W. C. Devereux (*Fellow*) was unveiled on 30th September by Sir Archibald Rowlands, G.C.B., Permanent Secretary to the Ministry of Supply, at the Fulmer Research Institute of which Colonel Devereux was the Founder.

MEMBERS' NEW APPOINTMENTS

R. ANDERSON (*Graduate*) has recently left the de Havilland Engine Co. Ltd., and is taking up an appointment as an Industrial Engineer with A. V. Roe (Canada) Ltd.

P. L. E. GALLIMORE (*Graduate*) has recently taken up employment in the Flight Test Department of A. V. Roe (Canada) Ltd.

L. S. GREENLAND (*Associate Fellow*), formerly Assistant Chief Designer with H. M. Hobson Ltd., has recently become Chief Designer of this Company.

CAPTAIN (E) C. W. JONES (*Associate Fellow*) has been appointed Director of Military Aircraft Research and Development (R.N.) at the Ministry of Supply.

AIR MARSHAL R. O. JONES (*Fellow*) has been appointed Controller of Engineering and Equipment at the Ministry of Supply. He was formerly Air Officer Commanding No. 24 Group, Royal Air Force.

GROUP CAPTAIN J. A. KENT (*Associate Fellow*) has been appointed Commanding Officer of the R.A.F. Station at Odiham, Hants.

VISCOUNT KNOLLYS (*Companion*) has been appointed to the Board of Vickers-Armstrongs Ltd.

W. H. LINDSEY (*Fellow*), Chief Engineer of Armstrong Siddeley Motors Ltd., has been appointed a Director of the Company.

S. H. MASTERS (*Associate Fellow*) has recently taken up a post in the Design Office of Canadair Ltd., Montreal.

WING COMMANDER E. G. MONK (*Associate Fellow*) has relinquished his post as Liaison Engineer of Sangamo Weston Ltd. and has been appointed Technical Sales Manager of the Aviation Division of Elliott Bros. (London) Ltd.

D. PRITCHARD-JONES (*Graduate*), formerly with A. V. Roe & Co. Ltd., has recently taken up an appointment as an aircraft stressman with the English Electric Co. Ltd., Warton Aerodrome.

R. A. J. REGAN (*Graduate*) has recently taken up an appointment as a Structural Test Engineer with Canadair Ltd., Montreal.

AIR COMMODORE G. SILYN-ROBERTS (*Fellow*) has been appointed Director of Military Aircraft Research and Development (R.A.F.) at the Ministry of Supply.

T. SMITH (*Associate Fellow*) has recently taken up the position of Senior Wind Tunnel Designer with English Electric Co. Ltd., Warton Aerodrome.

GROUP CAPTAIN L. SNAITH (*Associate Fellow*), formerly at the Royal Aircraft Establishment, has been appointed Security Officer at the National Aeronautical Establishment at Bedford.

W. J. TROTMAN (*Graduate*) has recently taken up an appointment as a Design Engineer with the Lockheed Aircraft Corporation of California.

G. M. WATSON (*Associate Fellow*) has recently taken up an appointment in the Design Office of Canadair Ltd., Montreal.

A. E. WOODWARD-NUTT (*Fellow*) has been appointed Principal Director, Research and Development (Aircraft) at the Ministry of Supply.

G. A. WOOLVET (*Associate Fellow*) has recently been appointed Electro-Mechanical Engineer in the Research and Development Department of the Sperry Gyroscope Co. Ltd.

DIARY

LONDON.

November 12th.
MAIN LECTURE AT THE WEYBRIDGE BRANCH. The First R. K. Pierson Memorial Lecture—Rex Pierson—An appreciation and the Lessons of His Work. Sir A. H. Roy Fedden, M.B.E., D.Sc., F.R.Ae.S. At Vickers-Armstrongs Ltd., Weybridge Works. 6 p.m.

November 18th.
GRADUATES' AND STUDENTS' SECTION. An Introduction to Helicopters. J. D. Sibley. 4 Hamilton Place, W.1. 7.30 p.m.

November 20th.
SECTION LECTURE. The Design of a Wind Tunnel Balance. L. E. Leavy and C. J. Saunders. 4 Hamilton Place, W.1. 7 p.m.

November 27th.
MAIN LECTURE. Photoelasticity and Aircraft Research. Colonel H. T. Jessop, T.D. Institution of Mechanical Engineers, Storey's Gate, S.W.1. 6 p.m. (Tea at 5.30 p.m.)

December 2nd.
GRADUATES' AND STUDENTS' SECTION. Aerodynamics of Wind Tunnel Design. J. C. Gibbings. 4 Hamilton Place, W.1. 7.30 p.m.

December 4th.
SECTION LECTURE. Air Traffic Control Today and Tomorrow. Captain V. A. M. Hunt. 4 Hamilton Place, W.1. 7 p.m.

December 16th.
GRADUATES' AND STUDENTS' SECTION. An Introduction to Aircraft Vibration. D. J. Mead. 4 Hamilton Place, W.1. 7.30 p.m.

December 18th.
A FULL DAY DISCUSSION ON FATIGUE. Chemistry Lecture Theatre, University College, Gower Street, W.C.1.

BRANCHES.

November 6th.
Southampton—Operational Requirements. Air Vice-Marshal G. W. Tuttle, C.B., O.B.E., D.F.C. Institute of Education, University of Southampton. 7 p.m.

November 10th.
Bristol—Structural Developments in Ships. J. C. Lawrence. Conference Room, Bristol Aeroplane Co. Ltd., Filton House. 6 p.m.

November 12th.
Brough—Meteorological Service for B.O.A.C. Comet Operation. E. Chambers. Electricity Showrooms, Ferensway, Hull. 7.30 p.m. Admission by ticket only.
Luton—Trainer Aircraft. Wing Commander Wroath. George Hotel. 7.30 p.m.
Weybridge—MAIN SOCIETY LECTURE. R. K. Pierson Memorial Lecture—Rex Pierson—An Appreciation and the Lessons of His Work. Sir A. H. Roy Fedden. Vickers-Armstrongs Ltd., Weybridge Works. 6 p.m.

November 13th.
Isle of Wight—The Development of the Bristol Proteus Propeller Turbine Engine. Dr. S. G. Hooker. Saunders-Roe Sports and Social Club, E. Cowes. 6 p.m.

November 14th.
Glasgow—Servo-Mechanisms. A. J. H. Cruickshank. Royal Technical College. 7.30 p.m.

November 17th.
Halton—Rocket Propulsion and Interplanetry Travel. A. V. Cleaver. Branch Hut, R.A.F. Station, Halton. 6.45 p.m.

November 19th.
Bristol—Britain's Economic Position. Sir Cecil Weir, K.B.E., K.C.M.G., M.C. (By invitation of the Institution of Production Engineers.) At Royal Fort Physics Laboratory, Bristol. 7.30 p.m.
Coventry—BRANCH AREA MEETING WITH THE BIRMINGHAM BRANCH. Helicopters. Raoul Hafner. Queen's Road Hall, Coventry. 7.30 p.m. Coaches will leave the Hall of Memory, Birmingham, at 6.30 p.m. (Free transport.)
Reading and District—Sabres in Korea. Lt.-Cdr. J. Bailey, R.N. At the Abbey Gateway Room, Abbott's Walk. 7.45 p.m.

November 20th.
Isle of Wight—Annual Dinner.

November 21st.
Leicester—Structure Weight. J. Taylor. The Lecture Theatre, Loughborough College. 7.15 p.m.

November 25th.
Bristol—Developing Fuels and Lubricating Oils for Aviation. C. B. Davies. The Conference Room, Filton House. 6 p.m.

November 26th.
Southampton—Structural Problems of Advanced Aircraft. H. H. Gardner. Institute of Education, University of Southampton. 7 p.m.

November 27th.
Isle of Wight—The Helicopter for Passenger Transportation. R. Hafner. Saunders-Roe Sports and Social Club. 6 p.m.

November 29th.
Halton—Visit to the National Physical Laboratory.

December 1st.
Derby—Metallurgical Problems Imposed by Stratospheric Flight. Major P. L. Teed. Rolls-Royce Welfare Hall, Nightingale Road. 6.15 p.m.
Halton—Lecture by a representative of Dowty Equipment Ltd. Branch Hut. 6.45 p.m.

December 3rd.
Luton—Airships. Lord Ventry. The George Hotel. 7.30 p.m.
Weybridge—Some Aspects of Airline Flying from the Pilot's Point of View. Captain R. Rymer. Vickers-Armstrongs Ltd., Weybridge Works. 6 p.m.

December 8th.
Bristol—High Altitude Balloon Flights. Professor C. F. Powell, F.R.S. The Conference Room, Filton House. 6 p.m.
Halton—Branch Night, followed by Committee Meeting. Branch Hut. 6.45 p.m.

December 10th.
Brough—Aircraft Propulsion. Professor A. D. Baxter. Electricity Showrooms, Ferensway, Hull. 7.30 p.m. Admission by ticket only.
Reading and District—Industrial Design and the Engineer. K. Brookfield. Abbey Gateway Room, Abbott's Walk. 7.45 p.m.
Southampton—First Mitchell Memorial Lecture. J. Smith, C.B.E. Institute of Education, University of Southampton. 7 p.m.

December 11th.
Isle of Wight—Annual General Meeting, followed by a Film Show. Saunders-Roe Sports and Social Club. 6 p.m.

December 12th.
Birmingham—Guided Missiles. W. H. Stephens. Birmingham Chamber of Commerce. 7.15 p.m.
Bristol—Engineering Associations' Joint Dance. The Royal Hotel. 7.30 p.m.

December 16th.
Bristol—Presidential Lecture. Dr. A. E. Russell. The Conference Room, Filton House. 6 p.m.
Glasgow—Lecturettes. Royal Technical College. 7.30 p.m.

December 17th.
Coventry—Films. Mr. E. G. Stout's films on flying boats from the Third Anglo-American Aeronautical Conference. The Wine Lodge. 7.30 p.m.
Weybridge—Fatigue—What it is and Some Ways of Reducing its Incidence. Major P. L. Teed. Vickers-Armstrongs Ltd., Weybridge Works. 6 p.m.

December 19th.
Weybridge—Annual Dance. St. George's Hill Tennis Club.

ASSOCIATE FELLOWSHIP EXAMINATIONS

The next Associate Fellowship Examinations will be held in the offices of the Society on Monday, Tuesday and Wednesday, 15th, 16th and 17th December. Particulars of time-tables and general arrangements will be sent to all candidates.

COMMONWEALTH FUND FELLOWSHIPS

Twenty General Fellowships, tenable for 12 months, are offered in 1953 by the Commonwealth Fund, New York, to men and women who are British subjects, not normally resident in or near the Americas and who are degree graduates of a University in the United Kingdom. Candidates may be married or single but should be over 23 and under 35 years of age on 1st September of the year of the award.

Particulars and application forms (which must be returned by *15th December 1952*) may be obtained from: The Warden, Harkness House, 35 Portman Square, W.1.

ELECTIONS

The following is a list of new members and transfers of membership of the Society:—

Associate Fellows

Joseph Savage Alford
Eric Harry Banfield (*ex Associate*)
Norman Oliver Brand (*from Graduate*)
Henry Horace Cadman (*from Associate*)
Ronald Frederick Cash (*from Graduate*)
Reginald Hawtrey Donkin
Brian Robert Foord (*from Graduate*)
Richard Francis Harrison (*from Graduate*)
Kenneth Roy Hickson (*from Associate*)
John William Frederick Housego (*from Graduate*)
Samuel Haydn Jones (*from Graduate*)
Ian Neil Munro MacDonald
Charles Ridout Shawyer
Alfred John Thorne
Kenneth Frank Venn
Philip Aubrey Wills

Associates

Graham Clifford Keen
Wallace William Ringland
Norman Denzil Carlyle Rowe
John Barry Treacy

Graduates

John Alexander Hope Bailie
Norman Arthur Barfield (*from Student*)
Kenneth Noel Corbett Bray
Michael Lawrence Camp (*from Student*)
Conway Andrew James Chiles
William Godfrey Fairhead
Jacques Grosjean
Roland John Moxon Hill
Michael John Hobday
Colin Randal Ivison
William Gordon Johnson
John Anthony Llewellyn
George Eric Martin
Roydon Frederick John Naish
Stuart Gregory Pountain
Keith William Stanley Richards (*from Student*)
John Maurice Roberts
Anthony Compton Southgate
Richard Edgar Thomas
Sydney Walmsley (*from Student*)
Edward Clement Weston (*from Student*)
Alan Robert White
Brian Stanley Wilkinson
Douglas Charles F. Williams

Students

John Henry Allen
Frank William Ashmole
Gurkirpal Singh Babra
Robert Baker
Norman Craig Balson
Antony James Bastick
Norman Bever
Thomas Johnson Black
Martyn Howard Bolus
K. S. Chandrashekaran
Richard Arthur Clarke
Burjor Sorabji Cooper
John MacDonald Lawson Dook
Anthony Leon Ells
David Eveleigh Gibbings
Michael John Goldsmith
Roy John Grainge
Frederick Brian Simpson Harnby
Edgar Thomas Harris
Frank Michael Ashley Hines
Eric Alexander Robert Jolly
Gordon Frederick Jones
Frank Littlehales
Richard Penderell Llewelyn
Frances John Charles Herbert Lock
Roger Joseph McNidder
Dennis Male
Brian Angus William Martin
Brian Albert Miller
Kenneth George Paul
Nigel Price
Norman Hugh Simmonds
Peter Alexander Smith
Joan Dorothy Targett
David Hugh Tipper
Alan Victor Waggett
Michael Barry Parker Watson
Anthony Wormell
Czeslaw Andrzej Zbrowski

Companion

William Scott Stewart

EIGHTH BRITISH COMMONWEALTH AND EMPIRE LECTURE

Maintaining Airworthiness in Operation

by

R. E. HARDINGHAM, O.B.E., F.R.Ae.S., M.S.L.A.E.

The Eighth British Commonwealth and Empire Lecture was given by Mr. R. E. Hardingham, O.B.E., F.R.Ae.S., M.S.L.A.E., before the Royal Aeronautical Society on 2nd October 1952 at the Institution of Mechanical Engineers, Storeys Gate, S.W.1. The audience included a number of distinguished guests, among them visitors from overseas and representatives of the Divisions of the Society.

Mr. G. H. Dowty, F.R.Ae.S., President of the Society, at whose suggestion the British Commonwealth and Empire Lectures were started in 1945, presided over the meeting. After welcoming the guests Mr. Dowty introduced Mr. Hardingham, outlining his career briefly. Mr. Hardingham was one of the original apprentices at the Royal Aircraft Establishment and in 1921 joined the de Havilland Aircraft Co. Ltd. Later he served for three years with the Air Ministry during which period he was associated with the Aeronautical Inspection Directorate and the Directorate of Technical Development. He joined the Air Registration Board on its formation in 1937, becoming Principal Surveyor in 1945. In 1947 he was appointed Secretary and Chief Executive and that same year became an Officer of the Order of the British Empire. Mr. Hardingham has represented the United Kingdom at a number of International Conferences.

1. INTRODUCTION

This paper deals primarily with a broad explanation of the arrangements in the United Kingdom for maintaining the airworthiness of civil aircraft in transport operation. Because the problem of the ever-increasing complexity of modern aircraft is very much to the fore at present, it also attempts to show how this has affected the task of the operator, the pilot, the engineer and the Airworthiness Authority.

Many qualities are demanded of the modern aeroplane: ability to fly fast and to carry large loads in all climates and weather conditions, by day and by night. It must do this with safety, regularity and comfort. These demands impose a truly enormous burden on all concerned because the performance is expected to be at least as good as that provided by surface vehicles, but in a medium which is fundamentally different and more difficult than all others.

The demand for speed has resulted in the building of aeroplanes with extravagant landing and take-off speeds, filled to the brim with devices such as hydraulics, pneumatics and electrics. This has made the provision of adequate safety and ease of maintenance more difficult to achieve; yet for healthy transport both are essential.

Faced with using the highly complicated aeroplane, the operator must provide superlatively trained personnel for both flying and maintenance duties and it is fortunate that British operators have, since the war, taken a most responsible attitude in their domestic rules and operations planning. This, in the main, has ensured that their aircraft have not been operated in adverse conditions and that they have not been flown or serviced by other than expert personnel.

For their part, the Airworthiness Authorities of the world have tried to keep pace with events, and procedures are constantly modified to suit the circumstances. The principle trends in Great Britain have been:—

(*a*) The elimination of unnecessary margins, with the consequence that safety requirements are now tailor-made to fit more closely particular types of flying in particular circumstances.

(*b*) The provision of much more data to assist the crew and operators to judge the suitability of the aeroplane for the flight.

(*c*) The extension of test procedures and maintenance methods to deal with the complex systems.

2. SCOPE OF PAPER

The paper contains three parts under the headings "Suitability," "Serviceability" and "Simplicity." Part I deals with the method for ensuring that the aeroplane is suitable in every way for the purpose for which it is to be used; Part II deals with the method for ensuring that the original standard of airworthiness is maintained from one flight to another; and Part III is a brief summary of personal views on desirable trends for the future. Under the heading "Suitability," it is not intended to dwell unnecessarily on the *derivation* of airworthiness design standards, but some reference to prototype certification is unavoidable. Under "Serviceability," avoidance of discussion of those aspects of maintenance which are well known, does not mean that their importance is in any way diminished.

PART I. SUITABILITY

3. INITIAL CERTIFICATION

Acceptance of a satisfactory standard of airworthiness for an aeroplane type is indicated when the prototype is granted an unrestricted Certificate of Airworthiness. This does not necessarily imply that the published requirements of the Airworthiness Authority are complied with in every detail but it does mean that the Authority is satisfied that, where variations from them have been required or accepted, the basic aim of the requirements has been achieved or improved upon. In accepting a prototype, there are many features, such as workmanship and good engineering practices, which are not covered by written requirements but which receive due attention.

The responsibility of the Authority does not end when the prototype certificate of airworthiness is granted, for it is necessary to ensure that all steps have been taken to enable the level of safety implicit in the initial certification to be maintained in day-to-day operations. In this connection there has been a marked change in the importance of the certificate. The old concept of "basic airworthiness" unrelated to operating circumstances, is fast disappearing. In its place, because of the diversity of operating conditions, we *must* think in terms of suitability for the conditions prevailing.

The issue of a modern certificate of airworthiness is contingent on the existence of a Flight Manual and of a Service and Instruction Manual. Together, these give the operator much of the information he needs; the first to judge the suitability of the aeroplane to the circumstances of its use, and the second to maintain the aeroplane's airworthiness. A certificate without this supporting data would be valueless nowadays.

4. DAY-TO-DAY SAFETY

The immediate task is to provide (as a result of investigations, including flying trials on typical routes) suitable information relating to the performance of the aeroplane and the conditions in which it may safely be operated, and to see that this information is properly used and that any laws enforcing its use are complied with.

Ideally it is desirable to achieve, for every flight of each aeroplane of a type, some minimum safety level. Unfortunately, this ideal cannot be achieved in practice since day-to-day variations in the state of the aeroplane will occur and it will not always be possible to match *exactly* the qualities of the aeroplane to its immediate intended use. Hence, the standard required in initial certification is found to be a little higher than that which can be expected for the least safe individual operations. Thus the Authorities, in the interests of practicability, must provide for some small day-to-day variation in safety standards.

5. FLIGHT MANUAL

The suitability of a modern transport aeroplane for a particular flight and its correct operation are explained in the flight manual. The document has legal status because of its official association with the Certificate of Airworthiness. Each invidual aeroplane has its own individual flight manual, although much of the information is common to all aeroplanes of the type. A consequence of the legal status of the flight manual is that the phraseology needs to be specific and unambiguous when submitted to critical analysis.

Figures 1 and 2 are photographs of a Comet Flight Manual and of typical information in it.

After a brief description of the aeroplane, which includes a statement as to whether it complies with requirements in respect of flight by night, at high altitudes, or in icing conditions, there is a section headed "Limitations." These are statements of the conditions outside which the aeroplane must not not be operated and include speed limitations, power-plant limitations, weight limitations, normal and emergency procedures, and so on. Then follow sections on "Handling" and "Performance."

The writing of airworthiness performance standards and the production of the flight manual are the responsibility of the Air Registration Board. The operational standards, which define minimum margins for take-offs and landing distances and obstacle clearance en route, are laid down by the Ministry of Civil Aviation through the medium of the Air Navigation Regulations.

The airworthiness and operational standards are complementary and enable a certain minimum performance to be enforced for public transport operations. But even without mandatory operational rules, it is absolutely essential to provide performance information and guidance to pilots on its use, because in the absence of authentic information, the most able and willing pilot could not, with certainty, ensure the safe operation of a modern transport aeroplane, without some sacrifice in payload.

6. PERFORMANCE INFORMATION

The section of the flight manual which includes performance is an indication of the outstanding trend in civil airworthiness requirements, namely the replacement of arbitrary minimum values by a stipulation that the aeroplane's characteristics and performance must be determined and scheduled. This results in a reduction in airworthiness margins and in their place must come a close operational control.

To appreciate the reasons for this trend, it is well to reflect on the scene before the Second World War. Most aeroplanes then had lower wing loadings and hence shorter distances to take-off and land. Moreover, the lower speeds and the general practice of flying in visual contact with the ground made forced landings, by day at least, a passably safe procedure. Long oceanic flights were not then routine operations. The commonly accepted level of safety was also lower.

For these reasons, it was necessary only to consider an aeroplane's performance with all its engines operating, and the requirements of the day specified a take-off not exceeding 500 metres, a not onerous all-engines-operating climb and a landing distance not exceeding 300 metres. How delightfully simple this sounds now. Those who complain of complicated airworthiness requirements would do well to consider how this has been occasioned by the complicated aeroplane of today.

In the past, pilots were expected to reduce landing and take-off weights when operational circumstances would appear to cause these distances to be exceeded if the maximum weights were used. This could only be done by a mixture of experience (first-hand and handed down) and intuition, because pilots had no agreed operational data to work to and no properly authenticated information on the performance of the aeroplane.

War-time developments have led to a generation of aeroplanes in which the demand for speed and range has resulted in high wing loading and high take-off and landing speeds, with poor prospects of safe forced landings. Unfortunately, engine failure rates have not decreased and, in these circumstances, personal judgment will no longer suffice. It is no longer fair to the pilot, or sound practice for the operator, to allow the take-off weight of a modern transport aeroplane to be assessed in the old-fashioned way.

To meet the conflicting demands of safety on the one hand, and load-carrying capacity on the other, has led inevitably to a close matching of the performance of the aeroplane to the circumstances of its use, the objectives being the establishment of a minimum level of safety for all air transport operations, which will be world-wide in application and uniform in effect whatever the climatic and geographical conditions.

In other words, the operator is asked to adjust the weight of an aeroplane so that a minimum performance is achieved in relation to each flight, *i.e.* runway lengths available for take-off and landing, and the avoidance of obstacles in the vicinity of the aerodrome and en route.

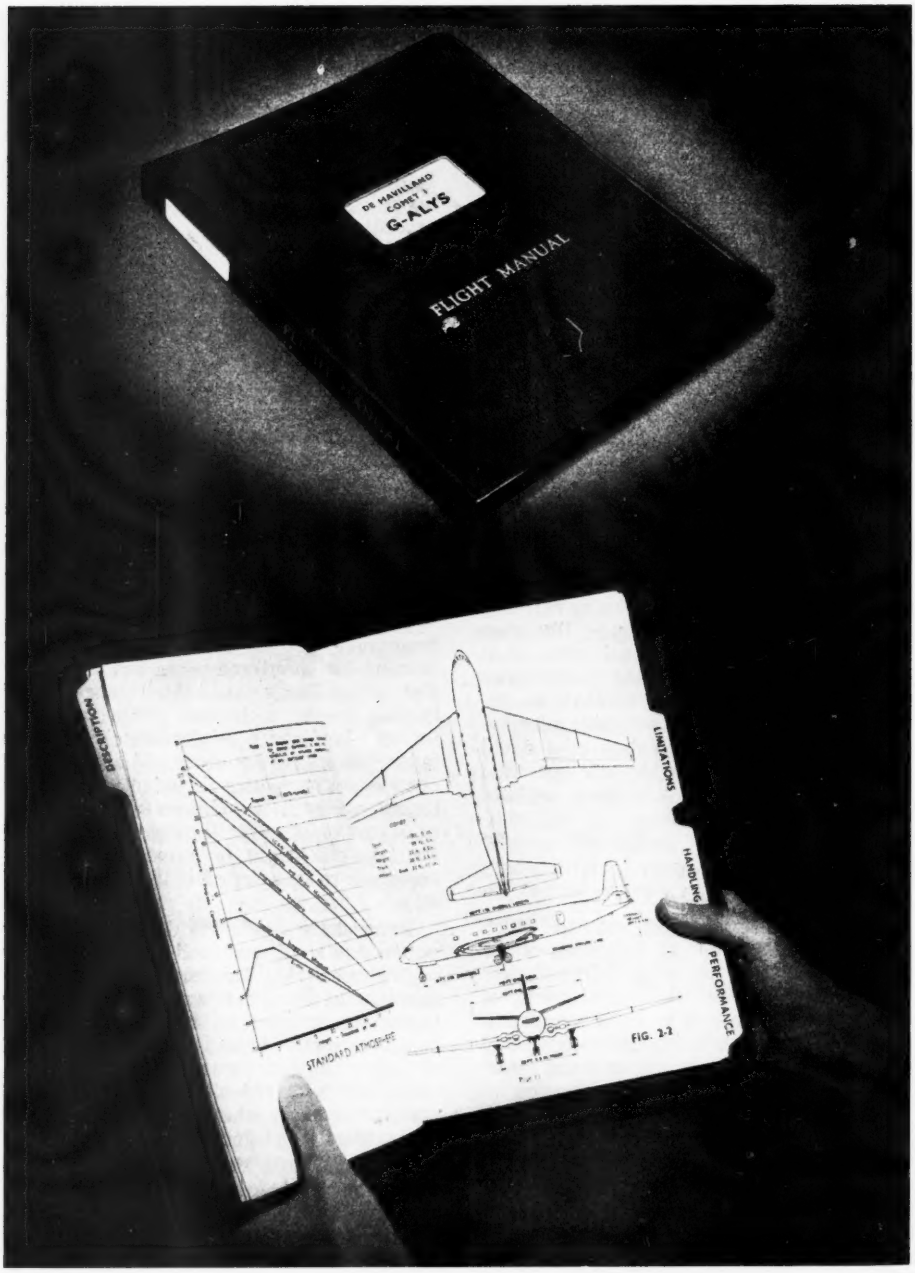

DE HAVILLAND
COMET 1
G-ALYS
FLIGHT MANUAL
DESCRIPTION
LIMITATIONS
HANDLING
PERFORMANCE
STANDARD ATMOSPHERE
FIG. 2-2

Fig. 1.

SECTION V

PERFORMANCE

GENERAL

CONDITION OF AEROPLANE

The performance information in this section relates to a standard de Havilland Comet Series 1 aeroplane in the following condition:-

Power Units	:	de Havilland Ghost 50.
Cabin Pressurisation	:	Air bleed for normal cabin pressurisation in operation when engine speed is 9,750 R.P.M. or below.
De-icing	:	No external equipment. The effect on performance of operating the air bleed for aeroplane de-icing is scheduled where appropriate.
Surface Finish	:	Low gloss finish.

AIRSPEEDS

The minimum control speeds, stalling speeds, safety speeds and the critical power unit(s) upon the basis of which this performance information was obtained are given in Section IV of this manual.

STANDARD ATMOSPHERE

The International Standard Atmosphere (I.S.A.) is defined in Figure 5-1 in this section.

HUMIDITY

It has been established in high air temperature conditions that a relative humidity of 65% has no appreciable adverse effect on performance.

PERFORMANCE GROUP

The performance is scheduled in accordance with the Group A requirements in the British Civil Airworthiness Requirements, Section D, Issue 2.

STATEMENT OF COMPLIANCE WITH AIR NAVIGATION (GENERAL) REGULATIONS SECTION VI

The speed for compliance with the regulations governing flight over water is 400 knots true airspeed.

Fig. 2.

The ability of the modern multi-engined transport aeroplane to continue its flight after an engine failure is now mandatory and the clearance of all obstacles with an engine inoperative is implicit in the modern level of safety.

The new airworthiness performance standards, by requiring certain performance minima with all engines operating or an engine inoperative, establish the maximum permissible weights, within the limits of the structural strength, for varying altitudes and temperatures. The performance data, together with corrections for operational variables, are incorporated in the flight manual which, as already stated, is part of the certificate of airworthiness.

7. THE USE OF PERFORMANCE DATA

A detailed treatise on how to use data in the flight manual cannot be attempted in this paper and, in any case, would need a special expert on the subject. However, a simple illustration will be given of how the weight of the aeroplane is adjusted to the peculiarities of a particular route using flight manual information and complying with operating rules.

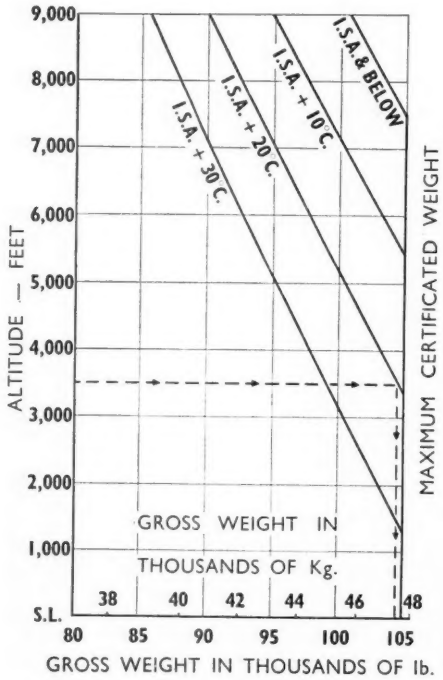


Fig. 3.—Maximum take-off weight for altitude and temperature.

The broad intention of this procedure is to ensure that the aeroplane can take off within the limits of the runway, land within the limits of the runway at the destination and any intended alternatives, and can clear not only obstacles in the environs of the aerodrome of take-off but also any high ground en route.

The actual calculation is more complicated to describe than it is to do. It is rather like filling in an income tax return; a little practice rapidly shows how to do so for a particular case, but a general description is inevitably cumbersome. The explanation is therefore confined to indicating the nature and object of the calculation.

The first step is to find the maximum weights permissible for take-off and landing, assuming in the first instance that there are no limitations for runway length, obstacle clearance and so on. This ensures that, in the prevailing conditions of temperature and altitude of the proposed operation, the performance of the aeroplane will not fall below a certain minimum. Fig. 3 shows typical weight-altitude-temperature (W.A.T.) curves for take-off. The landing curves are similar in appearance. From a knowledge of the altitude of the runways at take-off and landing, and the temperature, the corresponding maximum weights are readily obtained.

The second step is to relate the performance more closely to the proposed route. Figs. 4, 5 and 6 illustrate the aerodrome and route information required in a hypothetical case.

Consider first the take-off. For a large aeroplane in Performance Group A, the object is to ensure that

(*a*) the ground run does not exceed the length of concrete,

(*b*) if take-off is abandoned before a critical speed, the aeroplane will come to rest before reaching the end of the over-run,

(*c*) if engine failure occurs after the critical speed, the aeroplane will reach a satisfactory height before passing the first obstacle.

Thus, there are three important distances to consider and the flight manual shows the distances required for various altitudes, temperatures, runway gradients and head winds,

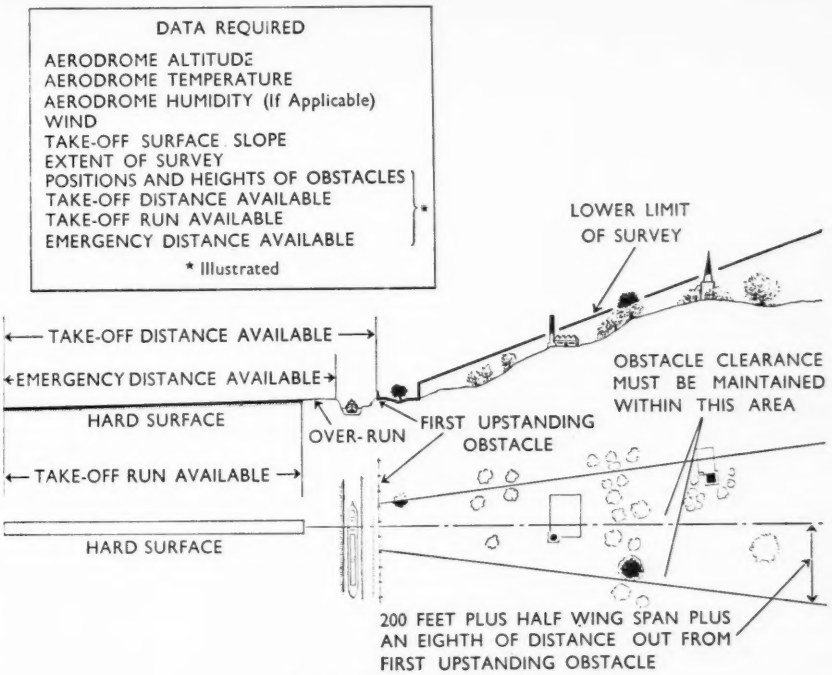


Fig. 4.—Route data: Take-off.

and aeroplane weights. If the distances available are likely to be more than adequate, this fact can rapidly be checked. When distances are short, it will pay to make two or three calculations, corresponding to various choices of critical speed. Clearly, if a low value of critical speed is chosen, the distance in the event of (*b*) is small and in the event of (*c*) is large, while if the critical speed is high the opposite obtains. Hence, for a particular aerodrome, there will be an optimum critical speed giving the highest safe weight. Fig. 7 shows a typical chart for assessing the take-off distance to 50 ft.; the other two distances are obtained from similar charts.

The next step is to check clearance of obstacles in the immediate vicinity of the aerodrome of take-off. The flight manual shows the flight path after take-off (often in the form of gradients of climb) in terms of temperature, altitude and weight. The actual figures quoted in modern British flight manuals are less than the performance which will normally be obtained. This difference, for larger aeroplanes, is associated with the fact that the flight manual performance assumes one engine to have failed. But, in addition, the performance is reduced to allow for other contingencies, so that the scheduled values are in the nature of guaranteed ones. By comparison of the obstacle profile in the vicinity of the aerodrome with that obtaining for the aeroplane, a safe weight is found.

If the clearance of obstacles after take-off is critical, optimum critical speed will be determined by balancing obstacle clearance, rather than take-off distance to 50 ft., against accelerate-stop distance.

Turning next to landing, Fig. 8 shows a chart in which the distance to land from a height of 50 ft. is given for various altitudes, temperatures and weights. The distance required to land must not exceed a certain percentage of the runway length, so the maximum landing weights at the destination and any alternative landing grounds, can be obtained. These figures for landing weight would be used if they were lower than that obtained for the W.A.T. curve.

By allowing for the fuel weight used in flight, it can then be found whether the

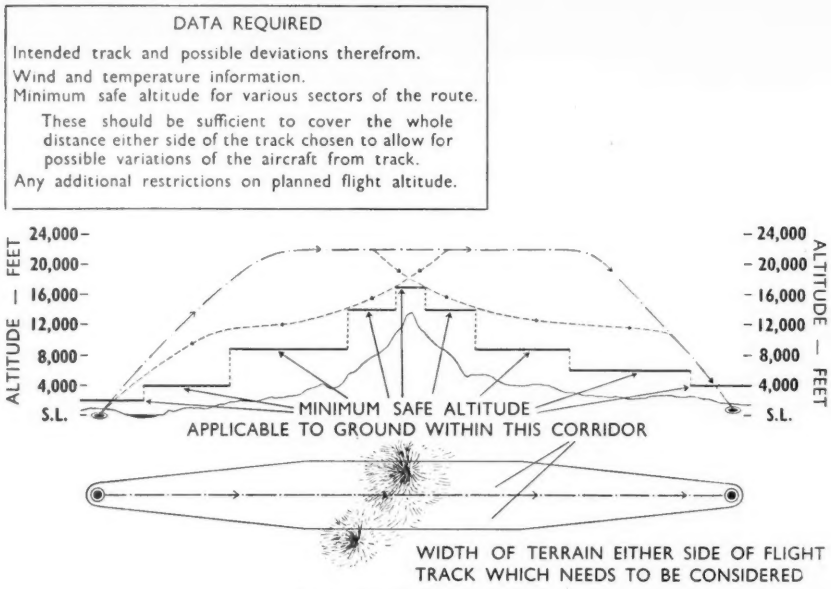

DATA REQUIRED
Intended track and possible deviations therefrom.
Wind and temperature information.
Minimum safe altitude for various sectors of the route.
These should be sufficient to cover the whole distance either side of the track chosen to allow for possible variations of the aircraft from track.
Any additional restrictions on planned flight altitude.
ALTITUDE — FEET
24,000
20,000
16,000
12,000
8,000
4,000
S.L.
MINIMUM SAFE ALTITUDE
APPLICABLE TO GROUND WITHIN THIS CORRIDOR
WIDTH OF TERRAIN EITHER SIDE OF FLIGHT TRACK WHICH NEEDS TO BE CONSIDERED

Fig. 5.—Route data: En-route.

landing requirement imposes a limit on take-off weight.

Finally, the performance en route is considered. The first step is to decide the minimum safe altitude for the particular sector. This altitude is decided by consideration of terrain clearance and other factors, such as the avoidance of icing levels, radio reception and traffic control procedures.

The flight manual shows the en route performance for the expected weight and temperature at various points along the route. The object is to ensure that wherever an engine failure occurs, it will not be necessary to fly below the minimum safe altitude. If the aeroplane has an adequate one-engine-inoperative performance at the minimum safe altitude at all points along the route, there is no need for further concern. It may be however, that at the high points, engine failure would cause the aeroplane to descend, in which case the high points must be crossed with an additional margin of height.

Figure 9 illustrates a simple case of the so-called "downhill" procedure. If the aeroplane is flying at height D_1C_1 and engine failure occurs at or after point D_1, it can safely clear the minimum safe altitude at D_2. Equally, if the failure occurs before C_1, the aeroplane can return to base clearing safely point C_2. A reasonable overlap period D_1C_1, during which the pilot can decide whether to go on or return, is necessary to allow for possible navigational errors, and so on. Thus the flight plan is drawn up on the basis that, with all engines operating, the aeroplane must be able to reach point D_1 before crossing the obstacle. There is no objection to flying above this level, although some other consideration (all-engines-operating performance, pressurisation, and so on) places a top limit to this (line EE on the figure).

Each of these calculations leads to a figure for maximum weight at take-off. The lowest figure is the safe weight for the operation.

In a particular case, the best sequence of calculations and the extent to which it is necessary to make full calculations rapidly become apparent.

8. THE FLIGHT CREW PROBLEM

It is impossible to deal at length with other contents of the flight manual, but even a casual glance through a modern manual shows immediately the fruits of the complexity referred to earlier. In a recent manual, for example, it was necessary to

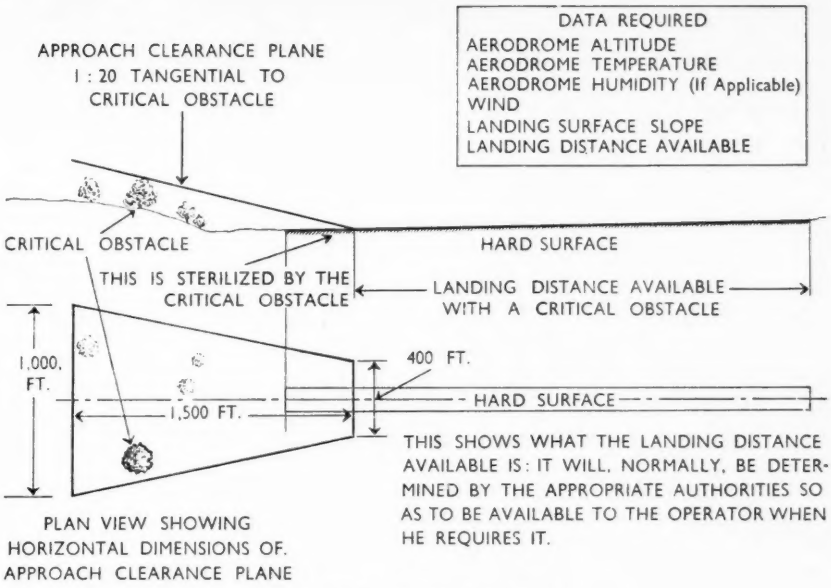


Fig. 6.—Route data: Landing.

include more than three closely printed pages to tell the crew of the sequence in which fuel should be used. In the narrow sense, this was necessary in order that strength and other conditions were met but, in the wider sense, is it right or proper that safe air transport should depend on such an exact prescription of human actions?

PART II. SERVICEABILITY

In describing the efforts of all those concerned with ensuring that the assumptions made in the certification of a protoype remain valid throughout the life of all aeroplanes of the type, it is necessary to make some reference to the past before dealing with present methods and speculating on future trends.

9. MAINTENANCE

Since 1919, the maintenance of transport aircraft has been the responsibility of the Licensed Aircraft Engineer, formerly known as the Ground Engineer and still, in many parts of the world, referred to as the "G.E."

For years, the method entailed daily and periodic inspections in accordance with the degree of knowledge and experience of the particular engineer, supported by brief instructions supplied by the constructor. This method was undoubtedly haphazard in that a great deal of unnecessary inspection took place and there was always a danger that some part of the aeroplane in need of attention was neglected.

After the Second World War, a move was made to persuade constructors to produce Service and Instruction Manuals of a wider scope. Examples of the manuals now being made available by constructors are shown in Figs. 10 and 11 (*see* pages 832 and 833).

The realisation that it was unreasonable to expect maintenance engineers to possess vast experience and precise judgment, and the demands of economy, led to the development of the Maintenance Schedule (Fig. 12, *see* pages 836 and 837) not only to take account of routine servicing, but the overhaul of those parts of the aircraft which hitherto had been overhauled at intervals of twelve months. At the same time, various systems for planning accurately the maintenance of aircraft were

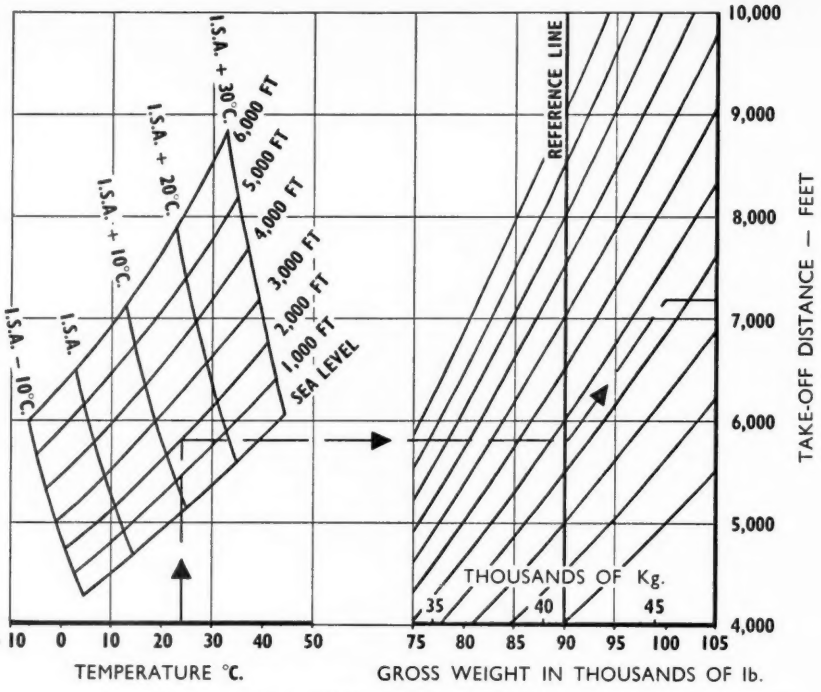


Fig. 7.—Take-off distance required.

introduced to ensure that each maintenance operation was done efficiently and in the shortest possible time.

Thus the maintenance and overhaul of aircraft became related to "flying hours completed" instead of to "calendar time."

So far so good, but what of the future? How can we ensure that the complicated transport aircraft is serviceable for periods of up to twelve hours per day throughout the year? Obviously it cannot be done if aeroplanes are pulled to pieces at set intervals to determine whether parts are worn or unserviceable, even when controlled by the best planned maintenance system and an efficient Maintenance Schedule.

Thus an attempt has been made to determine with a reasonable degree of accuracy how long the numerous parts, instruments and accessories will operate before the failure rate reaches unsatisfactory proportions and then to replace them with new or reconditioned parts.

This means that the recognised procedure of removing engines and propellers at agreed periods for overhaul is extended to other parts of the aeroplane and such parts given a "life."

A treatise on the subject of how to "life" a part of an aeroplane is not possible in this paper and remarks are confined here to expressing the opinion that each part of an aircraft must be designed to provide the maximum reliable life between overhauls, and that suitable "bench" or "rig" tests before the aeroplane goes into operation must establish that life. Later operating experience will vary the lives initially established. It follows that all parts, on completing their overhaul life, should be removed from the aeroplane to a workshop. New or reconditioned parts are then fitted and the aircraft is thus unserviceable for the minimum time.

Increased utilisation is only one reason for this conception of maintenance. Since experiencing the fatigue of aircraft structures, the "lifing" of parts has assumed new importance.

A final point is again that of complexity. Much of the equipment finding its way

into aircraft is of such complexity that the maintenance engineer cannot be given the responsibility for inspecting and servicing equipment such as the electric automatic pilot. His responsibility is confined to function testing and the removal of sealed containers at the expiration of a life, or in the event of a defect.

Thus the main objectives of component "lifing" are

(*a*) to keep the defect rate to a low level,
(*b*) to avoid the need for unplanned replacements (*i.e.* when defects have occurred), by making replacements at planned intervals,
(*c*) to allow complicated parts and components to be overhauled by specialists in properly equipped workshops.

When attempting to reduce the defect rate by planned replacement instead of allowing a component to run to failure, operators might assume that, although their safety standards had improved, the system entailed a great deal more work replacing components which were still serviceable. However, the process of fixing overhaul periods has, in the past, necessarily involved arbitrary decisions. Recently some thought has been given to a more rational approach. This leads to interesting possibilities, although it is perhaps early to reach firm conclusions.

As already stated, one of the objects of fixing a life is to minimise the frequency of defects. If this were achieved, safety would be improved and also, the need to remove defective items at inconvenient times would be reduced. The operator generally prefers to remove items according to a planned timetable rather than to await failure.

The first problem to be examined is the extent to which the fixing of life achieves its object. Through the courtesy of British European Airways, a very large number of defect records of instruments and equipment (excluding engines and propellers) have been made available for examination. The striking conclusion from the majority of these records is that the likelihood of a defect occurring is the *same* early in the life of the item as later in the life. Putting this another way, the defect rate (expressed as number of defects per 1,000 item-hours) remains fairly constant over the whole life of the item. Fig. 13 shows some typical records and it will be

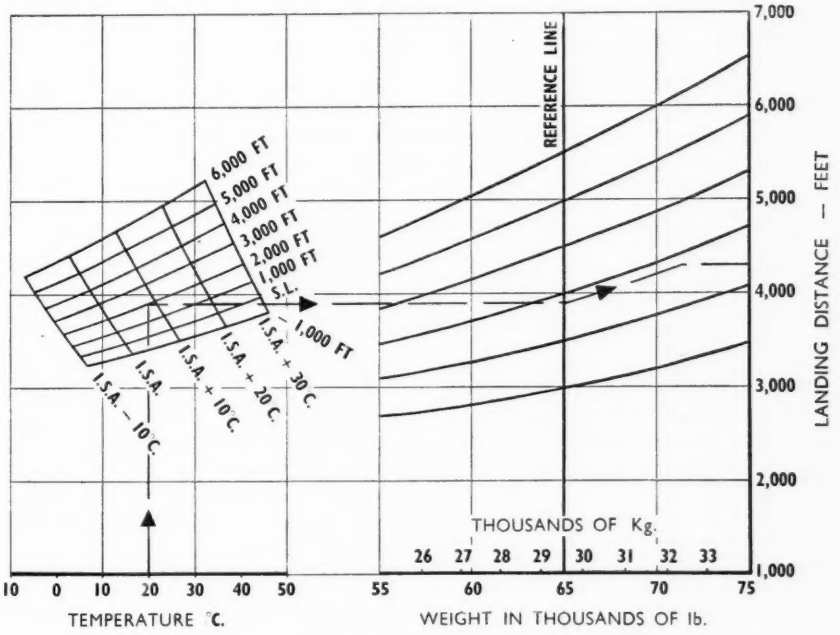


Fig. 8.—Landing distance.

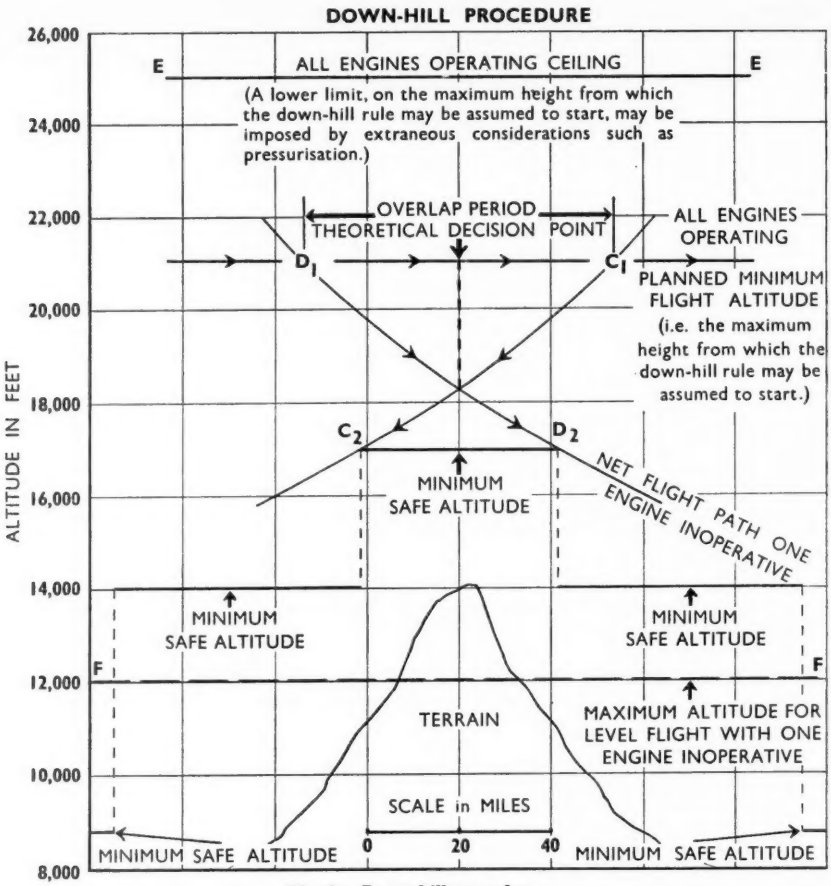


Fig. 9.—Down-hill procedure.

observed that the defect rate in some items is substantially constant; in some cases a gentle rise occurs, and in other cases the item literally improves with age.

The significance of this is that, in a large number of cases, if the lives had been fixed at a half or a quarter of their present values, the number of defects would not have been reduced and hence no improvement of safety or reduction of the work of removing defective items would have accrued.

Speculating on what would happen if the lives were increased beyond their present values, it seems probable that no increase of defect rate would occur unless, and until, some other form of failure (such as fatigue or wear) made its presence felt. If failures associated with fatigue or wear develop, these tend to concentrate around a certain number of hours of use and would thus cause a sharp rise in the defect rate. In these circumstances, fixing the life before the sharp rise occurred would obviously be beneficial.

If the defect rate of an item is high, then the proportion reaching the lives at present fixed is not large (Fig. 14). For such items, further increase or total abolition of life might not alter the defect rate materially. On the other hand for items with constant low defect rates, the majority survive the present life. Increasing life in these cases would be advantageous for reasons to be explained, but increases should be approached gradually in case of a sudden rise of defect rate.

The drawback of fixing a low life is that it results in the operator doing much more work by virtue of the very frequent removal of items. Thus, unless these low lives result in considerable reductions in defects (and hence reduction of the "unplanned" removals) the low life causes penalties with no offsetting advantages. The moral of Fig. 15 is that the life should be as high as possible in order to avoid unnecessary work, always provided that increase of life does not result in a sudden worsening of the defect rate.

This preliminary investigation shows that shortening lives does not generally improve the defect rate so that it is necessary to look to design, construction and possibly overhaul methods if defect rates are to be improved. Fortunately, the failure of these items is, in itself, rarely catastrophic, but rates of the order of 1,000 to 2,000 item-hours are extremely poor and materially increase the operators' burden.

With engines, the problem is usually more straightforward than with the remainder of the equipment of the aeroplane. Overhaul lives are fixed according to such factors as test results, experience and local conditions. Periods at which the various check inspections are to be made are fixed in the same way. Thus with new engines the periods are invariably low but are extended according to the results of operating experience. Fig. 16 illustrates this, showing the engine checks for three aeroplanes which have been in

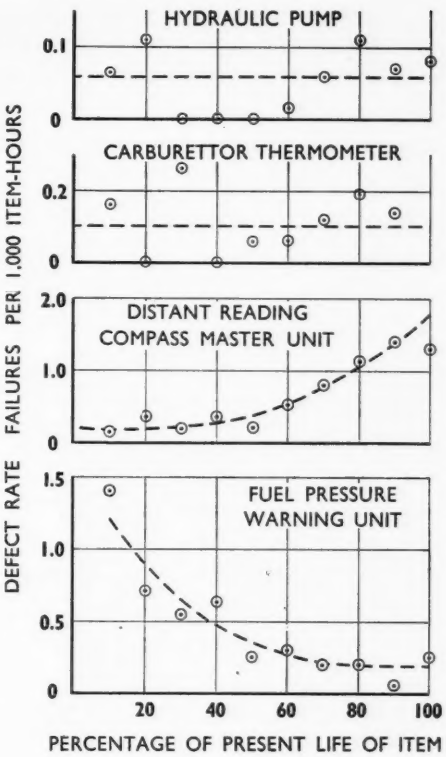


Fig. 13.

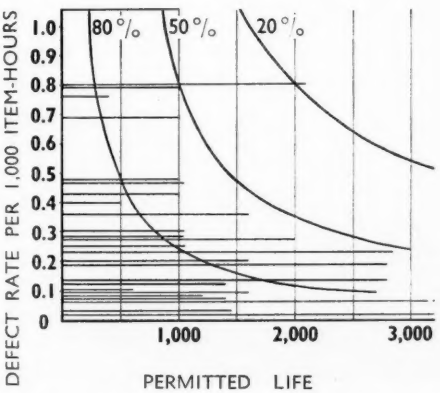


Fig. 14.—Horizontal lines are present permitted lives of several typical items. Curves show percentages which reach permitted life.

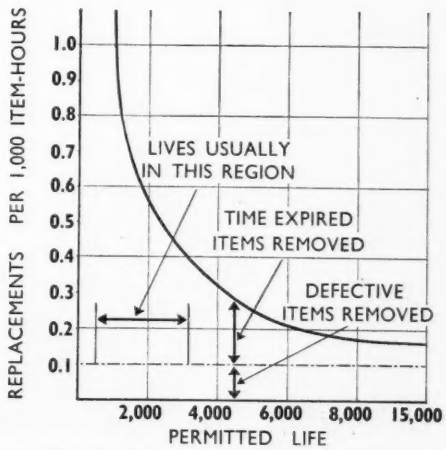


Fig. 15.—Typical example of effect of increasing life on amount of work done provided defect rate remains constant.

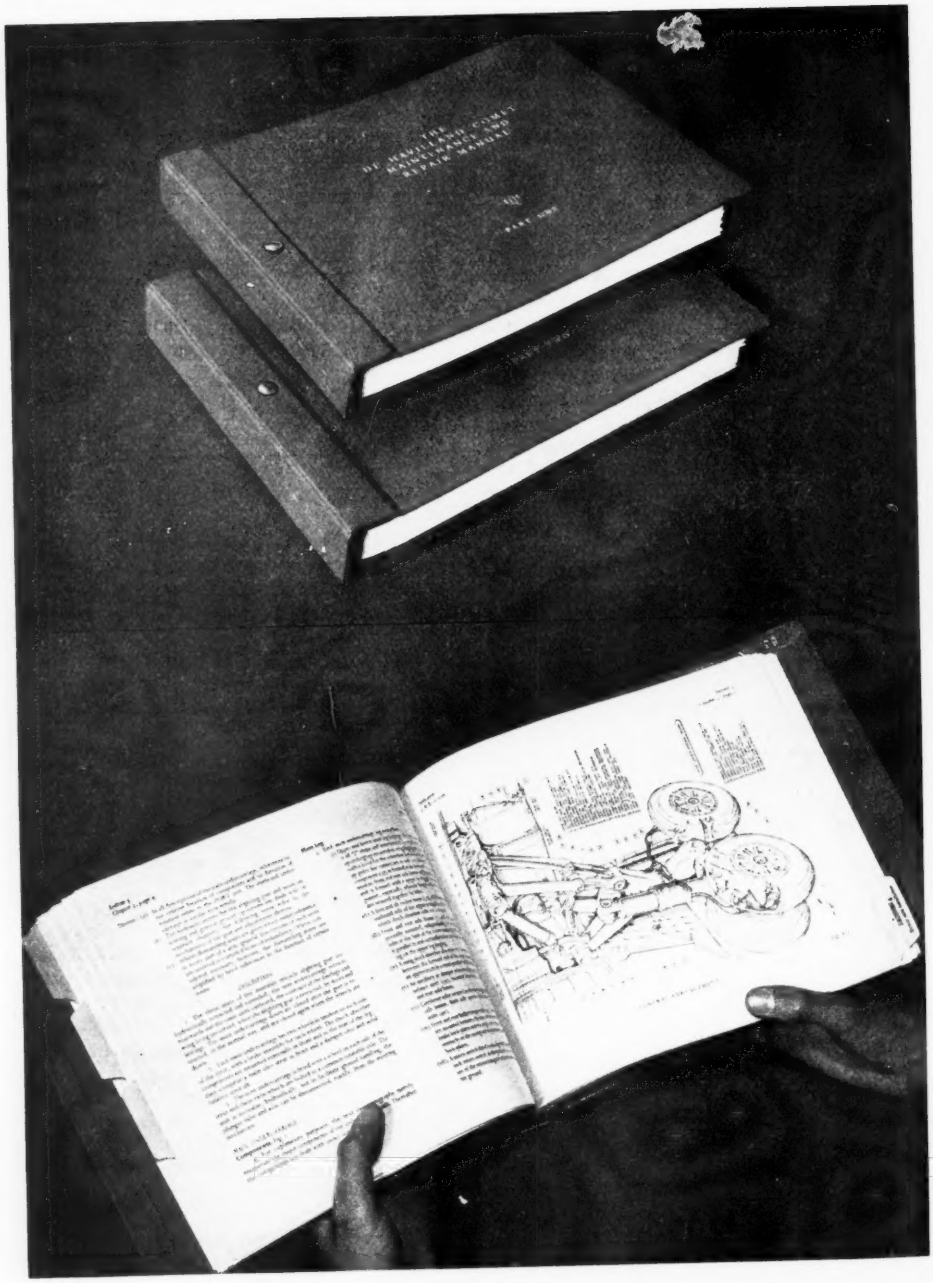


Fig. 10.

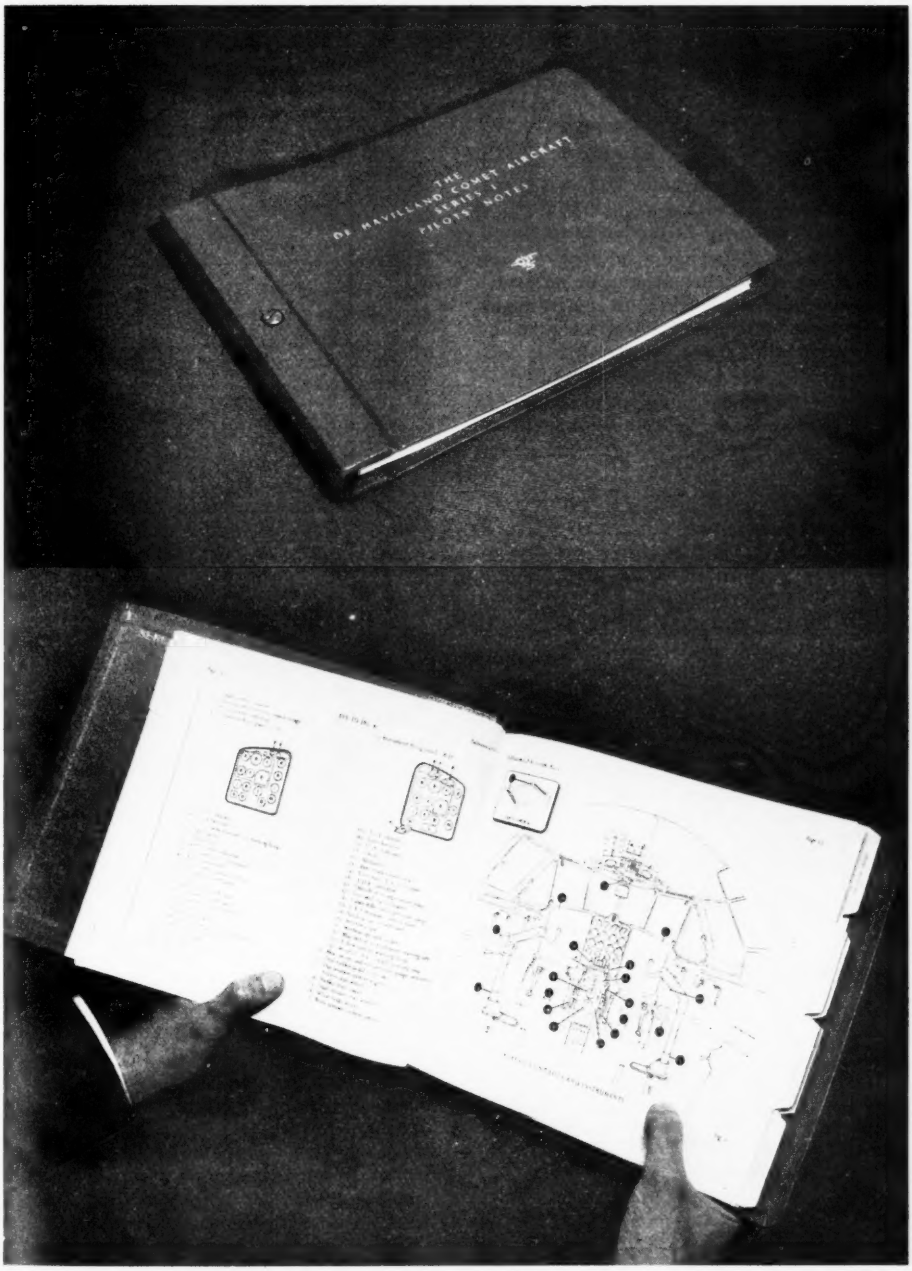


Fig. 11.

operation for different periods. Fig. 17 shows how the engine checks for one aeroplane have been extended since it began operation.

10. ENGINE RELIABILITY

Performance requirements are based on assumed engine failure rates and it is therefore extremely important to maintain engine reliability at least up to the assumed figure.

It follows that, if engine failures increase considerably in number, it may be necessary to stiffen take-off and climb performance requirements, operate at lower weights and limit the length of over-water flights, with resultant substantial economic penalty.

On the other hand, if, in due course, the reliability of turbine engines can show a considerable improvement over present piston

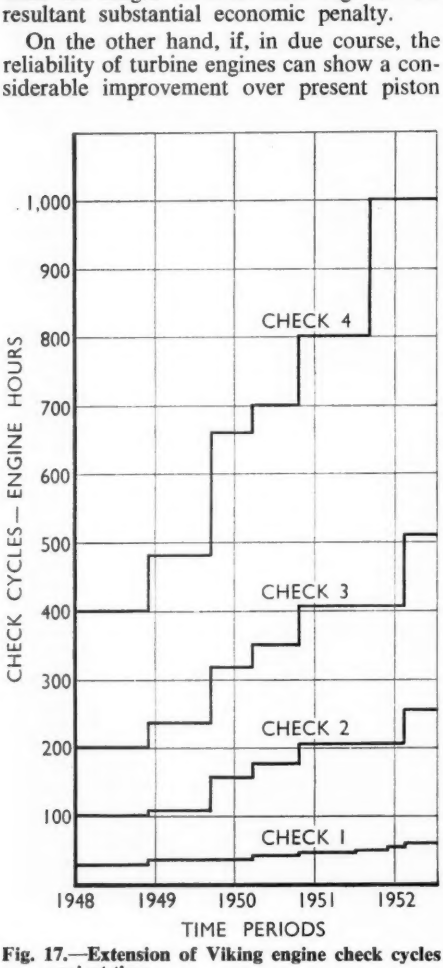


Fig. 17.—Extension of Viking engine check cycles against time.

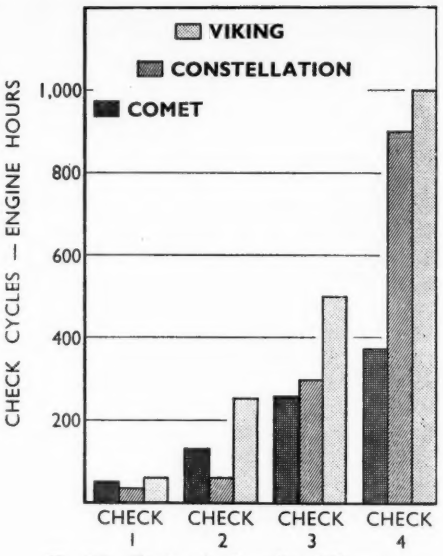


Fig. 16.—Engine check cycles of Comet, Constellation and Viking.

engines, it may be possible to ease performance requirements and operation rules.

When a new type of aeroplane begins operation, the engine failure rate will show whether the usual precautions such as the engine type test have been adequate, or whether additional maintenance precautions or easier operating conditions are necessary to maintain reliability. The latter is usually a temporary measure until suitable modifications are introduced, or the necessary maintenance knowledge and experience are acquired.

Figure 18 shows the trends of power failure rates and it will be noted that the older types are generally more reliable than the newer ones. The figures include the occasions when the pilot feathers the propeller as a precautionary measure. This may partly account for the lower rate for twin - engined aeroplanes as compared with the four-engined figure, because the pilot will be more reluctant to feather with only two engines. It is also noteworthy that several years often elapse before any substantial improvement in failure rate is achieved.

In deriving performance standards it is assumed that, generally speaking, the likelihood of one engine failure does not increase

the chances of a second engine failure at, or about, the same time.

Assuming complete independence of the power units, the risk of two engines failing is shown in Fig. 19 (*see* page 838). The rapid rise of the risk of double power failure as the ordinary single power failure rate increases, is rather striking. Because there are fewer engines to fail in a "twin" compared with a "four," the probability of double failure is reduced, but the consequences are much more serious.

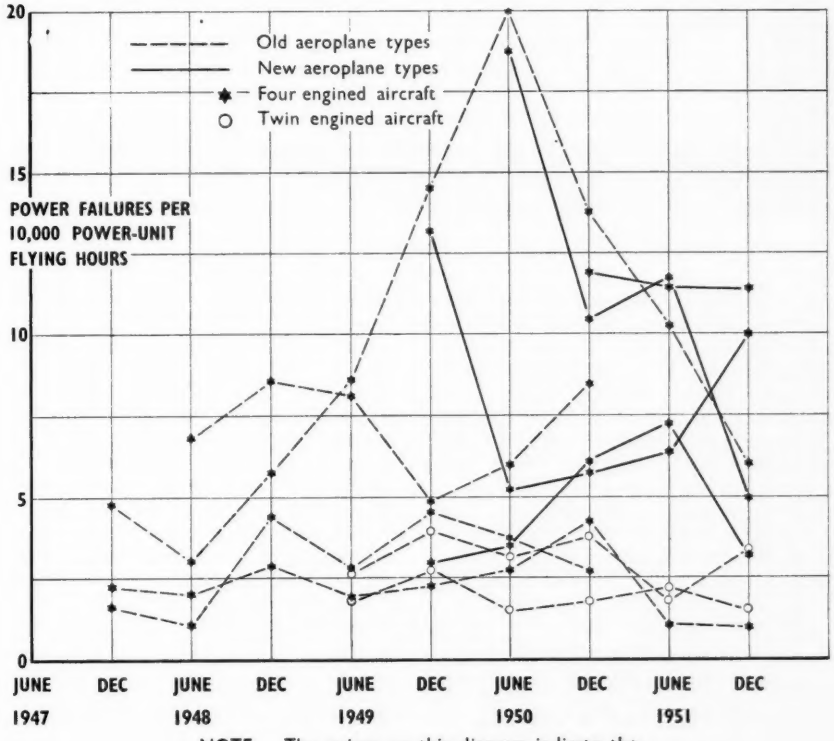
During initial certification of the prototype aeroplane, great care is taken to ensure that each power unit is mechanically and electrically independent. If this independence is not maintained, the consequence to safety could be alarming.

These precautions are likely to be wasted if, for example, all engines are changed at the same time and due to some error the same mistake in assembly or adjustment is made on each engine, as might happen through ignorance of a design change or by faulty instructions.

The staggering of engine replacements therefore seems desirable. Equally, a very careful check of fuel, oil and other fluids is essential because if these fluids are dirty or unsuitable, engine failures will occur at, or about, the same time.

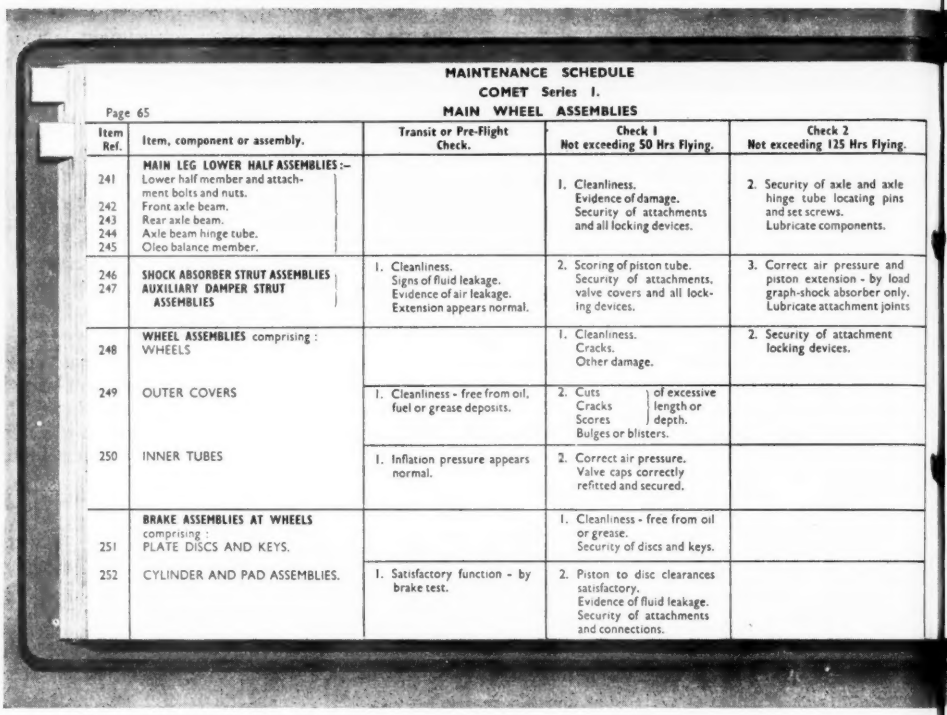
11. EQUIPMENT RELIABILITY

It is an unfortunate fact that many important items of equipment do not reach a sufficiently high standard of reliability and it is necessary to make provision for a high failure rate. Precautions such as duplication



NOTE. The points on this diagram indicate the average power-unit failure rate for the previous six months, compiled on the number of reported complete in-flight power unit failures.

Fig. 18.—Trend of in-flight power-unit failure rates (for U.K. scheduled operations).



MAINTENANCE SCHEDULE
COMET Series 1.
Page 65 MAIN WHEEL ASSEMBLIES

Item Ref.	Item, component or assembly.	Transit or Pre-Flight Check.	Check 1 Not exceeding 50 Hrs Flying.	Check 2 Not exceeding 125 Hrs Flying.
241 242 243 244 245	**MAIN LEG LOWER HALF ASSEMBLIES:–** Lower half member and attachment bolts and nuts. Front axle beam. Rear axle beam. Axle beam hinge tube. Oleo balance member.		1. Cleanliness. Evidence of damage. Security of attachments and all locking devices.	2. Security of axle and axle hinge tube locating pins and set screws. Lubricate components.
246 247	**SHOCK ABSORBER STRUT ASSEMBLIES** **AUXILIARY DAMPER STRUT ASSEMBLIES**	1. Cleanliness. Signs of fluid leakage. Evidence of air leakage. Extension appears normal.	2. Scoring of piston tube. Security of attachments, valve covers and all locking devices.	3. Correct air pressure and piston extension - by load graph-shock absorber only. Lubricate attachment joints
248	**WHEEL ASSEMBLIES** comprising : WHEELS		1. Cleanliness. Cracks. Other damage.	2. Security of attachment locking devices.
249	OUTER COVERS	1. Cleanliness - free from oil, fuel or grease deposits.	2. Cuts, Cracks, Scores } of excessive length or depth. Bulges or blisters.	
250	INNER TUBES	1. Inflation pressure appears normal.	2. Correct air pressure. Valve caps correctly refitted and secured.	
251	**BRAKE ASSEMBLIES AT WHEELS** comprising : PLATE DISCS AND KEYS.		1. Cleanliness - free from oil or grease. Security of discs and keys.	
252	CYLINDER AND PAD ASSEMBLIES.	1. Satisfactory function - by brake test.	2. Piston to disc clearances satisfactory. Evidence of fluid leakage. Security of attachments and connections.	

Fig. 12.

and the provision of alternative systems and emergency apparatus are necessary. These precautions themselves cause new airworthiness problems because increased complexity is usually the result.

An example is the unreliability of the ordinary radio valve. At one time, the use of the radio valve in aircraft was confined to radio apparatus, and the carriage of spare valves for replacement, when necessary, presented no great problem. Modern transport aircraft, however, which embody a great deal of electronic equipment, even affecting the basic control of the aircraft, demand a much higher standard and there should be greater consideration of reliability in the design and construction of such equipment.

Another example of the problems associated with complexity is to be seen in the power-operated control. The advantages of such a control for high-speed large aircraft need not be reiterated. But the airworthiness viewpoint is concerned only with its reliability. The well-designed simple manual control sets a standard of reliability (in its freedom from failure, jamming, or risk of incorrect assembly) which the power-operated control must seek to equal. Broadly speaking, " power - producers " whether hydraulic, electric, or pneumatic, are not reliable to the same degree as the human being. Nor are electric leads or hydraulic pipe lines so reliable for transmitting power as is a simple cable or rod. Hence duplication of the power systems becomes necessary. This is not the complete answer as it must be ensured that, in the event of one power system failing, there is sufficient time before catastrophe occurs to change to the other system.

The power-operated control also raises questions about human reactions. Since the operation of a power control is equivalent to turning on a tap or moving a switch, the feature of a manual control of natural " feel " is lost. Ways and means, all more or less complex, of building in artificial feel are available. But, from knowledge of human

MAINTENANCE SCHEDULE
COMET Series 1.
MAIN WHEEL ASSEMBLIES Page 66

Check 3 Not exceeding 250 Hrs Flying.	Check 4 Not exceeding 500 Hrs Flying.	Not exceeding 1000 Hours Flying.	Not exceeding 2000 Hours Flying.	Not exceeding 4000 Hours Flying.	Remarks, Maintenance Manual references etc.	
3. Evidence of wear at attachments.	4. Cracks. Corrosion. Deterioration of protective treatment. Other damage.			5. OVERHAUL.	Aircraft jacked - Check 3.	C
4. Fluid level correct—initial air pressure correct. Evidence of wear at attachments.	5. Cracks. Corrosion. Deterioration of protective treatment. Other damage.		6. OVERHAUL.			D E
3. Corrosion. Evidence of wear at axles.	4. **REMOVED FOR OVERHAUL** Replacement wheels correctly refitted, adjusted and secured.					F
	3. **REMOVED FOR OVERHAUL** Replacement covers correctly refitted and secured.					G
	3. **REMOVED FOR OVERHAUL** Replacement tubes correctly refitted and secured.					H
2. Excessive scoring. Cracks. Corrosion. 3. Cracks. Corrosion.	3. **REMOVED FOR OVERHAUL** Items correctly refitted, adjusted and secured and checked for correct operation.					J K

Fig. 12.

behaviour, it is impossible to be dogmatic in saying that one sort of feel is safer than another.

12. STRUCTURE RELIABILITY

Flying higher, faster and for longer periods has brought new problems to light, but it is only possible in this paper to give one or two examples. Any reference to fatigue of materials has been omitted intentionally.

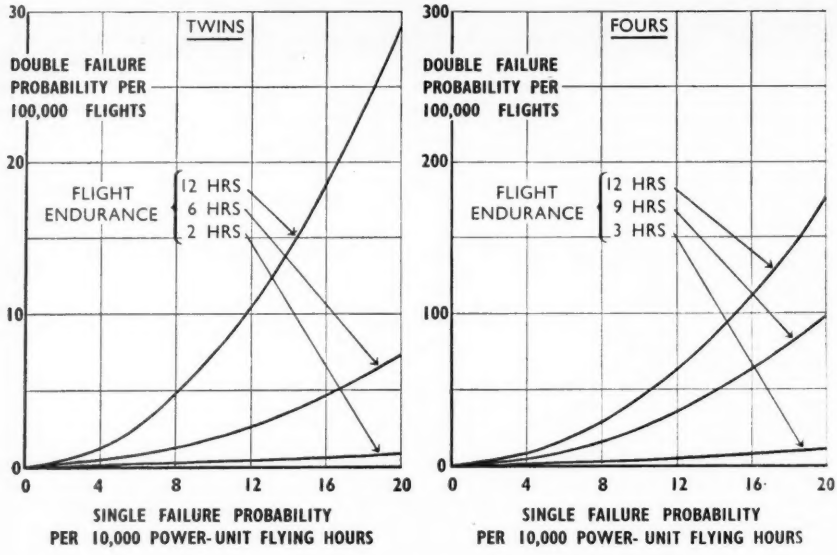
It is now well known that British jet turbine transport aircraft operate at heights of up to 40,000 ft. with a cabin pressure of about 8 lb./in.^{2}. This high pressure differential demands a cabin structure of great reliability, because explosive decompression and the effect on occupants cannot be tolerated.

Rapid loss of pressure is most likely to arise from a defective cabin window and in this paper comments are confined to the attention required during operation of an aeroplane such as the Comet.

Plastic transparencies can suffer from two main defects—cracking and crazing. No form of cracking is acceptable and, because cracks usually develop from crazing, action must be taken before cracks develop.

Crazing is caused by a combination of solvent vapour and tensile stress in the material. It is only acceptable when it is difficult to observe with the naked eye.

A recent technical instruction issued by the de Havilland Aircraft Company on this subject provides an excellent example of specialised guidance now being given to operators and maintenance personnel. This document gives full details, together with photographs, of the permissible types and amounts of crazing in plastic transparencies; it also shows clearly the type of crazing which is not acceptable and that which is acceptable after rectification by polishing out. The instruction has been issued after the constructors, by exhaustive tests, have established that explosive decompression is likely to be as rare as structural failure of a wing.



NOTE A larger scale is used for the twin-engined aircraft since a double failure on a twin is a more serious matter than on a four-engined aircraft.

Fig. 19.—Relation between single and double power unit failure probability and flight endurance for twin and four-engined aircraft.

13. MAINTENANCE OF PERFORMANCE

The validity of the published performance information in the flight manual depends on the gross performance on which it is based being a fair representation of the average performance of *all* the aeroplanes of the type, taking into account any slight variations of each aeroplane.

There is, therefore, a reasonable case for a comprehensive check by flight testing of each series or production aeroplane of the type, followed by a periodic check, say once a year, of the performance of each aeroplane.

As safety depends so much on performance, it is clearly necessary that aeroplanes in service should live up to their early promise and the flight tests, which need not be onerous, will show (*a*) whether the performance of the particular aeroplane is unduly low and (*b*) whether there is any significant downward drift in the average performance of the fleet.

The tests need only involve climbs totalling 10 to 30 minutes, depending on the type of aeroplane being considered, and from time to time the test results of the fleet would be collectively analysed. It would be necessary to consider the engineering history of the fleet, significant changes in maintenance practice and the modification state of each aeroplane.

At present there is still much to be learned about the deterioration of performance; possible causes of deterioration include

(*a*) excessive periods between engine overhaul which may lead to a falling off of power,

(*b*) repairs which leave the aeroplane less clean and increase drag,

(*c*) repairs which reduce thrust, *e.g.* excessive cropping of propeller blades,

(*d*) changes in specification of fuel.

The periodical testing of performance fits in well with the continuous maintenance and overhaul system since, from the point of view of checking fleet performance, it is desirable that aeroplanes should be tested in randomly selected mechanical conditions, *i.e.* not tested immediately following overhaul.

Operators may note that testing at random permits concentration on testing in the months in which the traffic offering is lowest.

There are, in the lifetime of a type of aeroplane, increases in maximum permissible weight as a result of modifications and general development. It is suggested that when a type of aeroplane has been in operation for two or three years, if significant statistics are available, it should be possible to increase the operating weight, or the scope of operation which it may undertake, on the grounds of proven reliability or on the grounds that the fleet performance is better than originally provided for in the airworthiness performance requirement.

PART III. SIMPLICITY

In the space available, it has been shown how the task of operating and maintaining the modern transport aeroplane is tending to become increasingly onerous. Accident statistics, which show a low percentage of accidents due to lack of airworthiness and a high percentage due to human error, merely indicate, in the author's opinion, that the operation and maintenance of the modern complicated aeroplane make far too great a demand on the skill and vigilance of air crew and engineers.

A great deal of energy and manpower is being directed to the human problems of training, organisation, physical skill and the provision of technical data, but can air transport become safe and acceptable in competition with surface transport if super humans are required to manage it?

Operators of large aircraft are turning to the synthetic training of air crew by flight simulators. The flight simulator is a most expensive but exact replica of the cockpit found in the corresponding aircraft and, by means of a complex electronic system, creates in the cockpit correct responses to any actions by personnel under training. Again, in the narrow sense, this is necessary, but in the wider sense, would it be necessary but for complexity? Surely the regrettable lack of uniformity of design and arrangement of crew compartments contributes to this problem and to the accidents due to crew error.

Undoubtedly the greatest single contribution to safety is the provision of low speeds for take off and landing. The demand for high cruising speeds has led to high wing-loading and, because speed-lowering devices (flaps, and so on) have not kept pace, stalling and landing speeds are much too high.

Assuming the demand for high cruising speed remains, devices are necessary for low flight speeds of the order of 50 m.p.h. in order that the operations of take-off and landing become less hazardous and less difficult for the pilot to execute. Apart from the *obvious* gain in safety, such complex devices as modern brakes and reversing propellers might thus become redundant and, in addition, the economic gain in runway lengths would be enormous.

Finally, too many accidents are due to the aeroplane hitting the ground in poor visibility and the development of approach and navigation aids which tell the pilot *exactly* where he is (and present the information in a form *not* requiring great skill in interpretation) would be another step forward in the quest for safety in air transport operations.

It is my opinion that air transport in its present form should be regarded as a measure of our ambition rather than our achievement. Let us not be too dazzled by statistics; after all, tightrope walkers do not often fall off the wire. Too often it seems that a kindly Providence, rather than our own efforts, gets us out of serious trouble. The aeroplane of today is a transport vehicle of enormous potential; but there must be a period of consolidation of effort devoted to making the vehicle more reliable, and less exacting on the people who fly and maintain it; we have come a long way, there is no discredit in taking a breather. The attitude we should adopt seems to me to be summarised in the words of Macbeth, "To be thus is nothing, but to be safely thus."

As was customary there was no Discussion of the Lecture but a vote of thanks was proposed by Mr. B. S. Shenstone, F.R.Ae.S.

MR. SHENSTONE: Unaccustomed as he was to praising the A.R.B. there did come a time when praise was due. Naturally they groused about the A.R.B. but, after all, they had built it themselves and they ran it themselves and so why should they not worry about it and try to improve it? It was rather like the man who built a fence round his house to keep the wolves out and then complained about the fence

being there: he might move it about and put it in different positions but he never took it away, and he did not think anyone had any intention of trying to remove what some of them considered an obstacle. A few days previously the designer of an aircraft had said, "I find it harder and harder to get a certificate of airworthiness for my aircraft," to which a competitor of his had replied, "Oh well, of course the A.R.B. is becoming more knowledgable!"

Apart from anything else the Aircraft Industry gained by the ability and knowledge of the A.R.B. not only technically but financially, because it set a standard which helped them in the export of their flying vehicles, so that it would redound to their credit if their standards were high, and particularly if they were demonstrably higher than those of other people.

He personally had found the A.R.B. very co-operative indeed but not easy in argument, and he thought sometimes of the American expression, "I am from Missouri, I will believe you if you show me." Possibly there might be an English expression developed over the years, when a man would say, "I am from Brettenham House . . . !"

He had much pleasure in proposing the vote of thanks to Mr. Hardingham.

Following the Lecture a Dinner was given by the Council at 4 Hamilton Place, W.1, at which the following were present:—

Mr. Carl Agostini, A.R.Ae.S., Director of Civil Aviation—Trinidad; Captain L. R. Ambrose, London Manager—Qantas Empire Airways Ltd.

Dr. A. M. Ballantyne, T.D., A.F.R.Ae.S., Secretary of the Royal Aeronautical Society; Air Commodore F. R. Banks, C.B., O.B.E., M.I.Mech.E., F.Inst.Pet., F.R.Ae.S., Principal Director of Engine Research and Development at the Ministry of Supply, Member of Council; Mr. E. C. Bowyer, C.B.E., Director of the Society of British Aircraft Constructors; Mr. J. W. S. Brancker, A.R.Ae.S., International Affairs Officer—B.O.A.C.; Sir John S. Buchanan, C.B.E., F.R.Ae.S., Past President of the Royal Aeronautical Society; Captain J. Bush, O.B.E., A.F.C., Manager of New Zealand National Airways Ltd.

Mr. S. Camm, C.B.E., F.R.Ae.S., Director and Chief Designer, Hawker Aircraft Ltd., Member of Council; Group Captain C. Clarkson, A.F.C., A.F.I.A.S., A.F.R.Ae.S.; Professor A. R. Collar, M.A., D.Sc., F.R.Ae.S., Sir George White Professor of Aeronautical Engineering, University of Bristol, Member of Council.

Mr. E. B. Dove, A.R.Ae.S., Designer in Charge (Special Projects), D. Napier & Son Ltd., Member of Council; Mr. G. H. Dowty, F.R.Ae.S., President of the Royal Aeronautical Society; Mr. B. A. Duncan, O.B.E., Whit.Ex., B.Eng., A.M.Inst.C.E., A.M.I.Mech.E., F.R.Ae.S., Director—Dowty Equipment Ltd.

Mr. G. R. Edwards, C.B.E., B.Sc., F.R.Ae.S., Chief Designer (Aircraft Section) Vickers-Armstrongs Ltd., Vice-President of the Royal Aeronautical Society; Mr. A. G. Elliott, C.B.E., F.R.S.A., M.S.A.E., M.I.Mech.E., F.R.Ae.S., Joint Managing Director and Chief Engineer, Rolls-Royce Ltd.

Sir William S. Farren, C.B., M.B.E., M.A., F.R.S., F.R.Ae.S., Technical Director of A. V. Roe & Co. Ltd., Vice-President of the Royal Aeronautical Society; Sir A. H. Roy Fedden, M.B.E., D.Sc., M.I.Mech.E., Hon.F.I.A.S., F.R.Ae.S., Past President of the Royal Aeronautical Society, Member of Council.

Air Marshal Sir Victor Goddard K.C.B., C.B.E., M.A., A.F.R.Ae.S., Principal of the College of Aeronautics, Cranfield.

Mr. A. A. Hall, M.A., F.R.Ae.S., Director, Royal Aircraft Establishment, Member of Council; Mr. N. J. Hancock, A.F.R.Ae.S., Ministry of Supply (Aeronautical Inspection Department), Member of Council; Mr. R. E. Hardingham, O.B.E., F.R.Ae.S., M.S.L.A.E., Secretary and Chief Executive to the Air Registration Board, British Commonwealth and Empire Lecturer 1952.

His Excellency M. A. H. Ispahani, High Commissioner for Pakistan.

Mr. N. U. Jayawardena, Deputy Governor of the Central Bank of Ceylon, Member of the Ceylon Delegation to the Prime Ministers' Economic Conference; Mr. E. T. Jones, O.B.E., M.Eng., F.R.Ae.S., Principal Director of Scientific Research (Air), Ministry of Supply, Member of Council.

Mr. G. R. Kamat, Member of the Indian Delegation to the Prime Ministers' Economic Conference; Air Commodore C. E. Kay, C.B.E., D.F.C., Air Officer Commanding, Royal New

Zealand Air Force, United Kingdom; Mr. D. Keith-Lucas, B.A., M.I.Mech.E., F.R.Ae.S., Chief Designer—Short Brothers and Harland Ltd.; Mr. H. R. P. A. Kotzenberg, Senior Trade Commissioner for the Government of the Union of South Africa, Member of the South African Delegation to the Prime Ministers' Economic Conference.

Captain A. G. Lamplugh, C.B.E., F.R.Ae.S., F.R.G.S., Underwriter and Principal Surveyor, British Aviation Insurance Co.; Mr. R. L. Lickley, B.Sc., D.I.C., M.I.Mech.E., F.R.Ae.S., Chief Engineer—Fairey Aviation Co. Ltd., Member of Council; Mr. N. V. Lough, Treasury Official for the Government of New Zealand, Member of the New Zealand Delegation to the Prime Ministers' Economic Conference.

Brigadier General Sir Osborne Mance, K.B.E., C.B., C.M.G., D.S.O., Companion of the Society; Mr. P. G. Masefield, M.A., M.Inst.T., F.R.Ae.S., Chief Executive, British European Airways, Vice-President of the Royal Aeronautical Society; Mr. Eric Mensforth, C.B.E., M.A.(Cantab), M.I.Mech.E., F.R.Ae.S., President of the Helicopter Association.

Mr. John Nash, A.F.R.Ae.S., President of the Southern Africa Division of the Royal Aeronautical Society; Mr. H. J. Neethling, Acting Deputy High Commissioner for the Union of South Africa.

Sir Arnold Overton, K.C.B., K.C.M.G., M.C., Permanent Secretary to the Ministry of Civil Aviation.

Mr. J. Lankester Parker, O.B.E., F.R.Ae.S., Master of the Guild of Air Pilots and Air Navigators; Colonel R. L. Preston, C.B.E., A.F.R.Ae.S., Secretary-General of the Royal Aero Club; Captain J. Laurence Pritchard, C.B.E., Hon.F.I.Ae.S., Hon.F.R.Ae.S., Secretary of the Royal Aeronautical Society 1925-51, Member of Council.

Mr. E. V. Read, Civil Aviation Air Liaison Officer to the High Commissioner for Australia; Mr. J. A. Ross, Trans-Canada Air Lines; Sir Archibald Rowlands, G.C.B., M.B.E., Permanent Secretary to the Ministry of Supply.

The Rt. Hon. Duncan Sandys, M.P., Minister of Supply; Mr. B. S. Shenstone, M.A.Sc., F.R.Ae.S., Chief Engineer, British European Airways, Member of Council.

Mr. J. D. Tudhope, Civil Aviation Attaché to the High Commissioner for Canada; Mr. W. Tye, O.B.E., B.Sc., F.R.Ae.S., Chief Technical Officer, Air Registration Board, Member of Council.

Mr. W. R. Verdon-Smith, M.A., B.C.L., J.P., Joint Assistant Managing Director—Bristol Aeroplane Co., Ltd.

Sir Hubert Walker, C.B.E., Chairman—West African Airways Corporation; Mr. W. H. Whelan, London Manager—Aer Lingus; Mr. L. C. Williams, B.A., A.F.R.Ae.S., Engineering Manager, Fairey Aviation Company of Australasia (Pty.) Ltd., Member of the Australian Division of the Royal Aeronautical Society; Mr. Philip A. Wills, C.B.E., A.F.R.Ae.S., Chairman —British Gliding Association; Mr. L. A. Wingfield, M.C., D.F.C., A.R.Ae.S., Solicitor to the Royal Aeronautical Society.

Fatigue Life of Wing Components for Civil Aircraft

by

KERI WILLIAMS, B.Sc., A.F.R.Ae.S.

1. INTRODUCTION

In the past attempts have been made to correlate the estimated load variations which the component will experience during a stipulated lifetime (in hours) with estimations of the fatigue strength (in cycles of loading) for typical structural components, such as wing spar boom joints, riveted joints, and so on. The trend of thinking so far has been that one should *design* for a certain fatigue life. In this paper it is shown that, even with the most careful attention given to the detail design of aluminium alloy components, it is not possible to attain what has been regarded hitherto as the minimum acceptable fatigue strength for typical structures, *i.e.* 2×10^6 cycles of $1g \pm 7\frac{1}{2}$ per cent. ultimate strength of the structure, based on present British Civil Airworthiness Requirements (Reserve Factor 1.0). There is no implied criticism of the criterion which is an ideal one, and if structures attained the criterion then the fatigue life would be adequate.

The method of analysis is to start with the results of fatigue tests on typical components. It is shown that generally the results obtained have been disappointingly low and it is maintained that little improvement can be expected on these results. It is suggested that *control* of fatigue life by limiting the service life should be the method adopted rather than design for a certain life.

A new term "fatigue stress factor (S)" is introduced; this can be as high as 9.0 when the test results in cycles for failure for a certain stress range are compared with those for a polished bar specimen. S is different from the familiar static load stress concentration factor and can be three times as severe in its effect on fatigue test results.

Paper received September 1952.

Mr. Williams is Senior Design Surveyor with the Air Registration Board.

For load frequencies in flight, the results so far agree approximately on the *relative* magnitude of loads; so that by using a typical relative frequency curve, the absolute frequency of gusts to produce fatigue failure can be estimated by using the "cumulative damage" assumption that failure occurs when $\Sigma(n/N)=1$. This assumption is open to objection on many counts, but it is a convenient method, and at present it is the only one available for correlating load frequencies with fatigue strengths.

In the final results of the analysis, general assumptions have been made that below 15,000 feet a 50 ft./sec. E.A.S. gust is met *once* in *three* million miles travel and that above 30,000 feet a 50 ft./sec. gust is met *once* in *nine* million miles travel. These general assumptions are made for guidance only, when it is realised that more accurate information is available on fatigue test results than on the absolute frequency of load variations in flight.

No factors are introduced either on the magnitude of loading or on the estimated life in miles flown or in hours, since any analysis of the aeroplane fatigue life is approximate in the present state of knowledge. The final estimate of fatigue life can be factored down in an agreed manner if such an analysis were used as a basis for determining airworthiness fatigue testing standards.

NOTATION AND ABBREVIATIONS

E.A.S	equivalent air speed
g	acceleration due to gravity
N	number of repetitions of load at failure
n	number of repetitions of load
S	fatigue stress factor
U_e	gust speed
V	true air speed
V_c	design cruising speed

2. SUMMARY OF THE METHOD

To obtain an estimate of the fatigue strength of a wing component in relation to the loads which the component will experience in service, the following three stages have to be covered:—

(*a*) *Fatigue Tests.* In the laboratory the critical wing components are subjected to fatigue tests to failure at particular load ranges.

(*b*) *Load Frequencies.* By means of recording instruments in the aeroplane, such as counting accelerometers or *V*-*g* recorders, a cross section is obtained of load frequencies in flight and on the ground for a certain time period.

(*c*) *Correlation of Test Results and Load Frequencies.* Some simple convenient method is necessary for the correlation of (*a*) and (*b*). Attempts have been made to use the cumulative damage assumption[8] which has not given very satisfactory results. Another conservative method used has been to ignore the measured load frequencies but to ensure that the component has a fatigue strength comparable with that for components of other aeroplanes which have experienced a satisfactory trouble-free service life.

3. FATIGUE TEST RESULTS

Figure 1 shows the results of fatigue tests on structural components such as bolted joints, sockets, stringer brackets and riveted joints in different specifications of aluminium alloy material.

The mean load for these tests has been extrapolated from the referenced reports to a mean load of 20 to 25 per cent. ultimate strength. The upper and lower envelopes for these tests are designated by fatigue stress factors $S=3$ and $S=9$ respectively. This is done because the sections of the curves from 5×10^5 to 10^8 cycles approximate to the scaling down of the typical polished bar curve by one-third and one-ninth respectively.

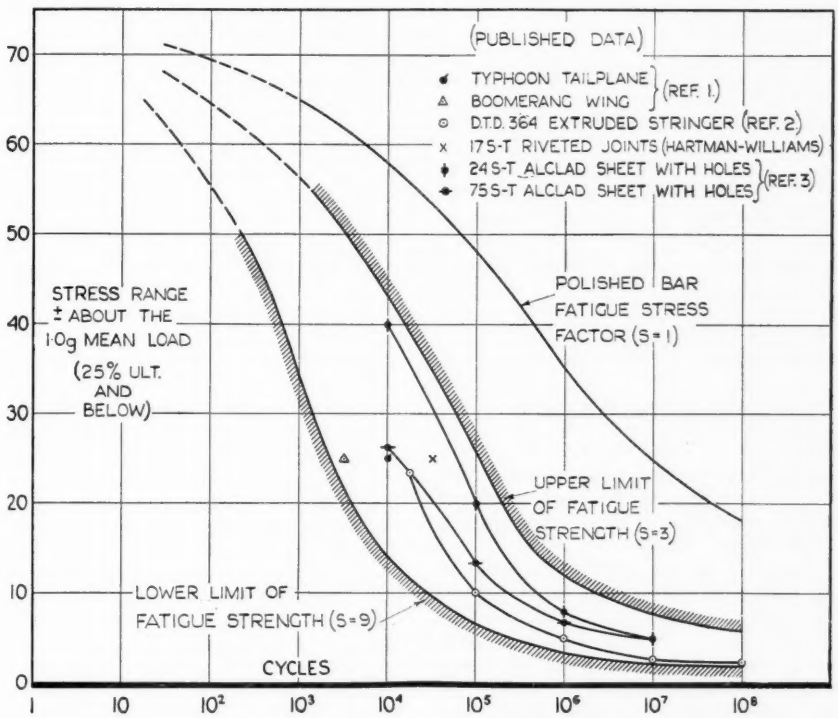


Fig. 1. Fatigue test results about 1.0*g* mean load.

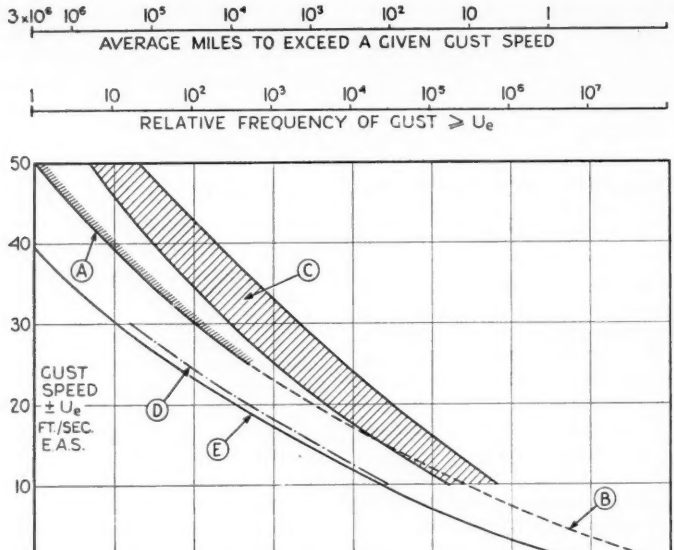

3×10⁶ 10⁶ 10⁵ 10⁴ 10³ 10² 10 1
AVERAGE MILES TO EXCEED A GIVEN GUST SPEED
1 10 10² 10³ 10⁴ 10⁵ 10⁶ 10⁷
RELATIVE FREQUENCY OF GUST ⩾ Ue
50
40
30
20
10
0
GUST SPEED ± Ue FT./SEC. E.A.S.
A
B
C
D
E
Ⓐ MEAN CURVE FOR V-g RESULTS ON HYTHE, PLYMOUTH, SOLENT, CONSTELLATION, LIBERATOR & VIKING } REF. 4
Ⓑ GUST RESEARCH FLIGHTS ON VIKING WITH COUNTING ACCELEROMETER (5,000 FT.) } REF. 5.
Ⓒ TIME BASED ACCELEROMETERS AND V-g RECORDS ON AMERICAN AIRLINERS (RHODE & DONELY) - (5,000 TO 10,000 FT.) } REF. 6.
Ⓓ B.E.A. CLEAR AIR GUST RESEARCH - (15,000 TO 37,000 FT.) REF. 7.
Ⓔ LOWER ARBITRARY LIMIT OF GUST FREQUENCY USED FOR ASSESSING FATIGUE DAMAGE IN FIG. 3. (CORRESPONDING TO I.C.A.O. RECOMMENDATION AT 37,500 FT.)

Fig. 2. Load frequencies in terms of gust velocities.

S does not necessarily correspond to the static load stress concentration factors for such structural components. In fact the maximum static load stress concentration factor for the structures of Fig. 1 is of the order of 3.5, so that in discussing these results, the term "fatigue stress factor S" has been introduced and should not be confused with the well-known stress concentration factor for static loading.

In addition, all the test results are for tensile loading only (zero upwards), and do not necessarily cover compressive stresses which may be induced on the ground or in the air by high magnitude down gusts. However, from the knowledge available at present, it can be assumed that the fatigue damage due to a compressive range of stress is the same as that for a tensile range of the same magnitude.

4. LOAD FREQUENCIES

The load magnitudes and corresponding frequencies that produce stress variations in the wing structure may be due to atmospheric gusts or pilot-induced manoeuvres in flight or on the ground due to taxying, take-off and landing.

Figure 2 shows the available information on load frequencies obtained from V-g recorders in cruising flight for the high velocity gust bands and from counting accelerometers for the lower frequency bands, for both British and American air liners.

Accelerations measured on one particular aeroplane have to be related to a common

basis so as to be applicable to another aeroplane, and the common basis used is *gust velocity*, even though a substantial number of the recorded accelerations may be induced by other causes, such as manoeuvres.

If a special study is to be made of one particular aeroplane type, then once accelerations have been recorded, these can be related directly to stress variations without the intermediate stage of relating accelerations to gust velocities and back again to stress variations.

The most reliable data linking up the relative frequency of the higher gusts above 25 ft./sec. E.A.S. with miles flown (necessary for the estimation of the absolute frequency of gusts) are given in Ref. 4. This indicates that a 50 ft./sec. E.A.S. gust, whether up or down, is expected to be met at altitudes up to 15,000 ft., once in three million miles of travel at or about the design cruising speed of aircraft.

The research with counting accelerometers on Viking aircraft[5] covers the lower end of the gust frequency curve up to 25 ft./sec. E.A.S. Thus the composite curve *AB* on Fig. 2 covering the records of Refs. 4 and 5 is taken as the basic frequency curve for gusts of magnitude zero to 50 ft./sec. E.A.S. below 15,000 ft. altitude.

The work of Rhode and Donely[6] in the United States is shown by the shaded portion (*C*) but this is of use only from a relative standpoint since, with these curves, a guess has to be made concerning the proportion of time spent by aircraft in rough air conditions (*i.e.* the path ratio). For simple comparison purposes between curves *C* and *AB*, it is assumed that they both agree at 10 ft./sec. E.A.S.

Very little high altitude (above 30,000 ft.) gust research work of any real value has been done so far. The most important work was done by the British European Airways clear air gust research project[7] and the results are plotted on curve *D*.

5. RANGE OF INVESTIGATION

(*i*) *Fatigue Strength Range.* $S=3$ to $S=9$ as shown on Fig. 5.

(*ii*) *Wing Ultimate Strength.* As the ultimate wing strength increases so does the corresponding fatigue damage increase for a certain gust magnitude. (This statement is based on the assumption that the ultimate strength of the wing is determined by the 50 ft./sec. E.A.S. gust case at V_c).

For example,

(*a*) For wing ultimate strength $= 4.0g$, proof strength $= 2.67g$ } Ultimate factor $= 1.5$.

± 50 ft./sec. E.A.S. gust $\equiv 1.67g$
$\equiv 41.7$ per cent. ultimate strength,

and ± 1.0 ft./sec. E.A.S. gust $\equiv 0.0334g$
$\equiv 0.84$ per cent. ultimate strength.

(*b*) For wing ultimate strength $= 6.0g$, proof strength $= 4.0g$ } Ultimate factor $= 1.5$.

± 50 ft./sec. E.A.S. gust $\equiv 3.0g$
$\equiv 50$ per cent. ultimate strength,

and ± 1.0 ft./sec. E.A.S. gust $\equiv 1.0$ per cent. ultimate strength.

Thus, as the wing ultimate strength increases, gusts of identical magnitude will produce loads which are a progressively higher percentage of the wing ultimate strength with resulting greater fatigue damage per cycle.

The calculations have been made for wing ultimate strengths of $4.0g$, $4.75g$, $5.5g$.

It is realised that, while the aircraft continues on its flight, using up fuel, the all-up weight decreases so that the $1.0g$ condition becomes a decreasing percentage of the ultimate wing strength. Also a gust of a certain magnitude will produce an increasing effect in terms of "g," but since the unit lift is decreasing, the overall effect on the wing stresses will probably remain appreciably constant during the flight. This has been checked and found to hold good for two aircraft types, one a typical four piston-engined aircraft, and the other a high altitude jet aircraft.

6. CORRELATION OF TEST RESULTS AND LOAD FREQUENCIES

Figure 3 illustrates the use of the cumulative damage assumption[8]. This assumption maintains that if a material specimen is subjected to loads which correspond to

(*i*) a steady stress X,

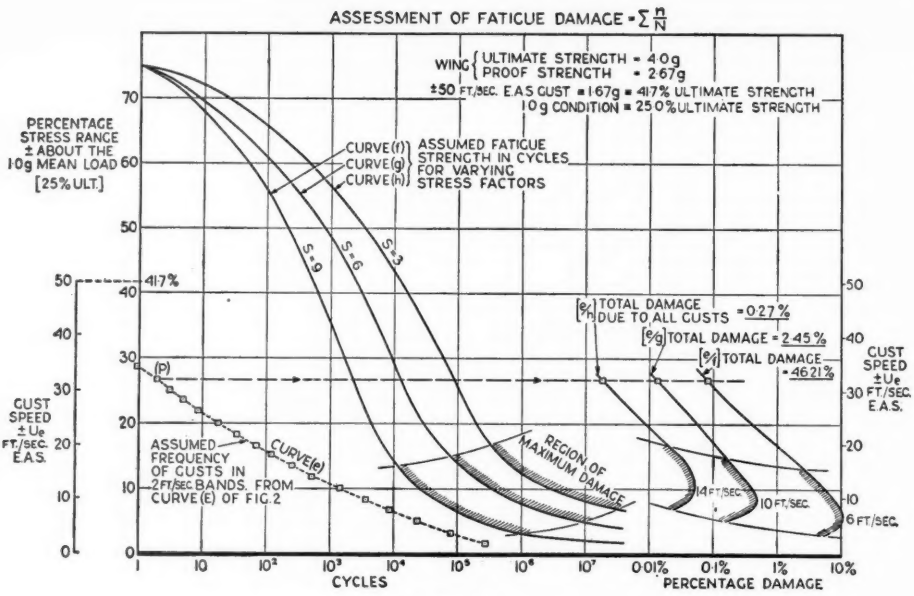

ASSESSMENT OF FATIGUE DAMAGE = Σ n/N
WING { ULTIMATE STRENGTH = 4·0g / PROOF STRENGTH = 2·67g
±50 FT./SEC. E.A.S GUST = 1·67g = 41·7% ULTIMATE STRENGTH
1·0g CONDITION = 25·0% ULTIMATE STRENGTH
PERCENTAGE STRESS RANGE ± ABOUT THE 1·0g MEAN LOAD [25% ULT.]
CURVE (f) ASSUMED FATIGUE STRENGTH IN CYCLES
CURVE (g) FOR VARYING
CURVE (h) STRESS FACTORS
S=9
S=6
S=3
41·7%
[e/f] TOTAL DAMAGE DUE TO ALL GUSTS = 0·27%
[e/g] TOTAL DAMAGE = 2·45%
[e/h] TOTAL DAMAGE = 46·21%
GUST SPEED ± Ue FT./SEC. E.A.S.
(P)
ASSUMED FREQUENCY OF GUSTS IN 2 FT/SEC BANDS. FROM CURVE (E) OF FIG. 2
CURVE (e)
REGION OF MAXIMUM DAMAGE
14 FT/SEC.
10 FT/SEC.
6 FT/SEC.
CYCLES
PERCENTAGE DAMAGE
0·01%
0·1%
1%
10%

Fig. 3.

(*ii*) an alternating stress $\pm Y$ about X as mean,

and the application of $\pm Y$ is repeated, then the material will be fatigued to some extent. If failure under this repeated load takes place after N repetitions, then the cumulative damage assumption maintains that each load repetition will damage the specimen to the extent of $1/N$ and the fractional damage after n repetitions will be n/N.

Thus, with a knowledge of the load variations arising from an estimated number of gust magnitudes about a certain mean ($1g$), it can be assumed that $\Sigma n/N = 1$ to produce a complete fatigue failure.

There are two main factors which indicate that the validity of the cumulative damage assumption is open to question:—

(*a*) The amount of laboratory research work substantiating the damage rule is not significant. The results obtained indicate that over-stressing will lower the fatigue stress limit and that under-stressing will raise the limit.

(*b*) The spectrum of stress cycles estimated to occur during the service life of an aeroplane should be considered in its correct sequence. During one flight a component may be subjected to a very small number of high stress cycles, a larger number of medium stress cycles and a high number of small stress cycles. This sequence will be repeated several thousand times during the service life of the aeroplane. The sequences of load application may have an important effect on the cumulative damage assumption.

However, since this assumption is the only means available for estimating the fatigue effect of load cycles of differing magnitude, it is used in the following analysis, irrespective of the defects mentioned, and on the average the effects may cancel each other.

Figure 3 illustrates for a $4.0g$ (ultimate wing strength) aircraft the application of the cumulative damage assumption to assess the total fatigue damage induced by the "packets" of gusts from curve e in 2 ft./sec. bands. Curve e represents the absolute frequency of gusts U_e in 2 ft./sec. bands derived from the relative frequency curve E of Fig. 2, which curve is the lower arbitrary limit of gust frequency giving the number of gusts $\geqslant U_e$. The datum for curve e is given by the assumptions that a 40 ft./sec. gust is encountered once in three million miles travel,

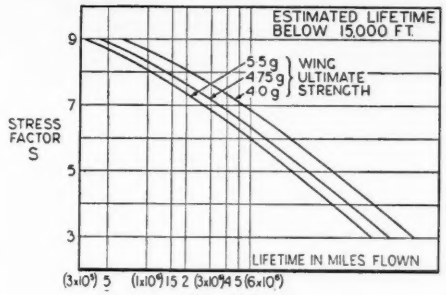


Fig. 4(a).

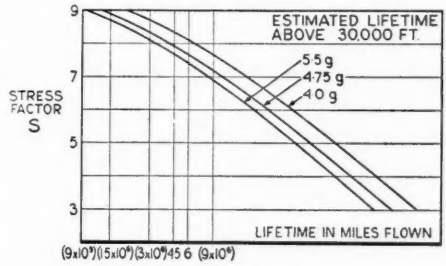


Fig. 4(b).

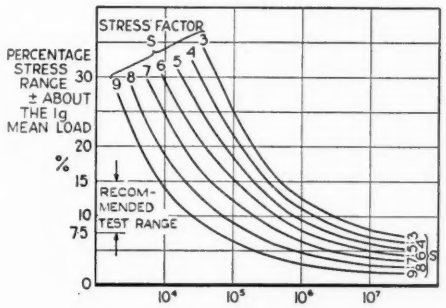


Fig. 5.

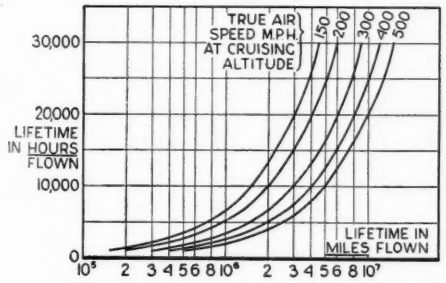


Fig. 6.

and that the number of up and down gusts is equal for the same gust magnitudes.

Example. The packet (P) on curve e represents two gusts of (31 to 33) ft./sec. E.A.S. (26.7 per cent. ultimate strength).

The corresponding fatigue strength at the various stress factors is

$$8.9 \times 10^4 \text{ cycles at } S=3$$
$$1.25 \times 10^4 \text{ cycles at } S=6$$
$$2.2 \times 10^3 \text{ cycles at } S=9,$$

and the corresponding fatigue damage at the various stress factors is

$$\frac{2}{8.9 \times 10^4} = 0.23 \times 10^{-4} \text{ at } S=3$$
$$\text{and} = 1.60 \times 10^{-4} \text{ at } S=6$$
$$\text{and} = 9.00 \times 10^{-4} \text{ at } S=9.$$

This example is not a good one, because of the low number of gusts involved, but it serves to illustrate the method.

If all the other "packets" of gusts are treated in the same way relative to the fatigue strength in cycles, the three damage curves are then developed on the right hand side of Fig. 3. The summation of the damage for all gusts for $S=3$, 6, 9, becomes 0.27 per cent., 2.45 per cent. and 46.2 per cent.

Thus for these respective stress factor levels $S=3$, 6, 9, the gust frequencies which would just produce fatigue failure, assuming $\Sigma n/N=1$ are given by curve $e \times (100/0.27)$, $(100/2.45)$ and $(100/46.2)$ respectively.

Figure 4(*a*) illustrates the fatigue life thus determined by the cumulative damage assumption for aeroplanes cruising *below 15,000 feet* in terms of stress factors and lifetime in miles flown for 4.0*g*, 4.75*g* and 5.5*g* aircraft. The datum used for the absolute gust frequency below 15,000 ft. is that a 50 ft./sec. E.A.S. gust is met *once* in *three* million miles flown.

Figure 4(*b*) is the corresponding one for aeroplanes cruising *above 30,000 feet*, the datum used being that a 50 ft./sec. gust is met *once* in *nine* million miles flown.

Figure 5 can be used for translating fatigue test results to the corresponding fatigue stress factor for use in Figs. 4(*a*) and 4(*b*).

Figure 6 is included for convenience to translate from miles flown to lifetime in hours for values of true air speed (150 to 500 m.p.h.).

7. CONCLUSION

No factors have been introduced either on the magnitude of the loading or on the estimated life, in miles flown or in hours, since any analysis of the aeroplane fatigue life must be approximate in the present state of knowledge. The final estimate of life can be factored down in an agreed manner if such an analysis were used as a basis for determining airworthiness fatigue testing standards. Operational factors, such as the value of the actual cruising speed which may be well below V_c, will have to be taken into account.

Since this paper was prepared about a year ago a great deal of research work has been done on the fatigue testing of structures and the collection of gust data but the general conclusions of the paper are not appreciably changed.

8. ACKNOWLEDGMENT

The author is indebted to the Ministry of Supply for permission to quote results from unpublished reports and to the Chief Executive of the Air Registration Board for permission to publish this paper. The views expressed in the paper are the author's own and not necessarily those of the Board.

REFERENCES

1. FISHER, W. A. P. A Comparison of the Endurance of Various Aircraft Structures under Fluctuating Loading. Unpublished Ministry of Supply Report.
2. POLLICUTT, F. H. (1949). Contribution to Discussion (Fatigue Resistance of Extruded Z-section Stringers in Aluminium Alloy to Specification D.T.D.364). *Journal of the Royal Aeronautical Society*, August 1949, p. 782.
3. LUNDBERG, B. K. O. and WALLGREN, C. G. E. (1949). A Study of Some Factors Affecting the Fatigue Life of Aircraft Parts with Application to Structural Elements of 24S-T and 75S-T Aluminium Alloys. (Flygtekniska Försöksanstalten (F.F.A.) Report No. 30, 1949.
4. STARKEY, R. Review of Gust Data from Civil Aircraft *V-g* Records. Unpublished Ministry of Supply Report.
5. TAYLOR, J. Design and Use of Counting Accelerometers. Unpublished Ministry of Supply Report.
6. RHODE, R. and DONELY, P. (1944). Frequency of Occurrence of Atmospheric Gusts and of Related Loads on Airplane Structures. N.A.C.A. A.R.R. Report No. L.4121, November 1944.
7. HISLOP, G. S. (1951). Clear Air Turbulence over Europe. *The Journal of the Royal Aeronautical Society*, April 1951.
8. MINER, M. A. (1945). Cumulative Damage in Fatigue. *Journal of Applied Mechanics*, Vol. 12, No. 3, 1945.

*Civil Aviation in the Second Elizabethan Era**

by

G. N. ROBERTS, C.B.E., A.F.C.

INTRODUCTION

The thought that the highlights of history four centuries ago will repeat themselves in our time is growing, but the word and the wish are not enough. It will need to enter the heart and soul of the people and the nation, if another prolonged period of prosperity, highlighted by the deeds of the adventurous, is to be ushered in.

THE REIGN OF ELIZABETH I

Let us go back in history, and try to find the parallel we seek.

"Once upon a time a white man climbed a tree in Panama and saw two oceans. The white man could not have dreamed of the Panama Canal, but he saw a nobler vision still, the dawn of England great at sea. This is the story of how he came down the tree and began the British Empire."

So began the opening paragraph of a chapter in a child's history book. The man was Sir Francis Drake, who laid the foundation of Britain's greatness at sea. Who cannot recall his voyages to Central America, where he looked out on both the Atlantic and Pacific Oceans? Who cannot recall his voyages round the world, and his sea battles with the fleets of Spain?

The name of Sir Francis Drake comes down to us through the years as an inspiration. Like Captain Cook, Scott of the Antarctic, Mallory and Irvine of Everest fame, and a host of others, he has set an example as an explorer and adventurer which will find a parallel today. Adventure in the second half of the twentieth century may be entirely different in character and everything points to the fact that man will find his strong lust for adventure in the scientific realm. With one outstanding exception, man appears to have performed most of the feats calling for a high degree of physical endurance, associated with the surface of the earth. I predict that Mount Everest will be climbed in the next decade.

Queen Elizabeth I, as she must now be known, encouraged and supported Sir Francis Drake in his endeavours to make Britain predominant at sea. In her many wrangles with Spain, she made it quite clear that the oceans of the world were to remain free and open to the commerce of all nations. The words she uttered to the King of Spain about the year 1585 were prophetic:—

"The use of the sea *and the air* is common to all and neither nature, nor public use, nor custom permit any possession thereof."

The phrase "history repeats itself," is, more often than not, applied to decline and fall, rather than to strength and progress. Let us therefore, in drawing a parallel between the reigns of Queen Elizabeth I and Queen Elizabeth II, start with the thought that in the new reign this great nation of ours, in association with other great nations of like thinking and ideals, will make history repeat itself in the realm of strength and progress.

THE REIGN OF ELIZABETH II

Queen Elizabeth II came to the throne at the same age, 25, as Elizabeth I and may have, with the grace of God, some 50 years to reign. She has already encouraged aviation when, as Princess Elizabeth, she flew to Kenya on the first part of her projected tour of Australia and New Zealand, cut short by the untimely death of her father. As Queen Elizabeth I encouraged Sir Francis Drake in her time, so Queen Elizabeth II and all the Royal Family have shown that they intend to encourage aviation, the industry upon which the future well-being of the British Commonwealth and the whole world will largely depend.

Although we in aviation today may not place ourselves in the pioneer category, those

*A paper read to the Auckland Branch of the New Zealand Division of the Society on 3rd July 1952. Mr. Roberts is General Manager, Tasman Empire Airways Ltd.

who accept our responsibilities a century or two, or even half a century from now, will think of us as such, so remarkable will be the development in that time. The younger men in the industry today look back with amazement on the deeds of those who launched aviation a mere 50 years ago. The next 50 years will see the real beginning of commercial mastery of the air, and it is in this period that the adventurous spirit and inventive genius of the original pioneers will bear its full fruit.

In an article published recently in New Zealand, Group Captain Dundas, under the caption "Here is John Cunningham, Elizabethan Adventurer," said, "Mark the name, mark the deeds, for both will appear in history books, as yet unwritten. I pick him as a man with the Elizabethan Spirit. The flight of the Comet through the Empire skies may be seen as an augury of things to come in the New Elizabethan Age. For the whole of space remains to be conquered."

That last sentence has great significance, for although the commercial conquest of the air will be started in the next half century, man still has much to learn of the problems associated with stratosphere and even troposphere flying. In the era that we are considering, activities will be confined more to the troposphere and lower stratosphere, but even now, scientists are discussing flights to and around the moon.

Aviation's call for more altitude has made meteorologists extend their knowledge into the lower stratosphere. Radar and the aeroplane have assisted them to collect data on upper air temperatures, wind velocity and direction, cloud formation, and so on for the first time. Not long ago, a B.O.A.C. pilot, flying a Comet, reported cloud at 50,000 ft., when the general belief was that it did not go above 35,000 ft. He also reported lightning at 44,000 ft., the highest ever known. Accurate weather forecasting will contribute in no small measure to safe and economic operation at high altitudes. Recently meteorologists have tracked narrow air streams, in the upper atmosphere, of velocity sometimes greater than 200 knots, and as yet the phenomena is unexplained. Their significance in flying may be very great if they can be proved constant and can be plotted accurately. As the mariners of yesterday used the "Roaring Forties," so the aviators of tomorrow may use the upper air streams to speed them on their way.

Commercial Exploitation

Let us probe into the future, say the next 50 years, which should still be within the life span of at least the younger members now taking an active part in aviation.

The world is poised today on the threshold of the air age. The first 50 years will be only the start of the commercial exploitation of the air, in much the same way as the 15th Century was the start of the commercial development of the mercantile marine.

May 1952 saw the commercial introduction of a new form of propulsion for aircraft—the first Comet flight over the London/Johannesburg route. This is real achievement, but within ten years travel at twice the speed accepted today, improved passenger comfort, greater reliability and safety, will have become commonplace.

The Brabazon and the Princess are possibly in advance of their time, but the research will not be wasted. For the time being they have merely proved that, as with ships, which grew from the humble 100-tonner to giants like the *Queen Mary* and *Queen Elizabeth*, the steps in building aircraft must be gradual, and must not advance beyond the airmindedness of the people and the technical knowledge of the day. An intermediate type, between 100,000 lb. and 250,000 lb., would have met more closely the frequency and capacity required today and in the immediate future.

The world, particularly the British Commonwealth, may yet pay the penalty for neglecting the development of the flying boat. Great are our maritime traditions, yet we have forsaken our birthright. The terms of reference of the Brabazon Committee, which first met in 1943, were to express "User Requirements." With the impetus that war gave to the development of landplanes, and the construction of airports, it is little wonder that all the crystal gazing imaginable could not convince the Committee that flying boats came within their term of reference. (The Saunders-Roe Princess resulted from an order placed by the Ministry of Supply.) That flying boats with performance and other characteristics equal to, or better than, their landplane counterparts can be built, has been established, for although construction has lagged through lack of orders, designers have not been idle.

In a foreword to Taylor and Allwards' book, "Wings for Tomorrow," Lord Brabazon has admitted that Britain has erred

in not pressing forward with the construction of flying boats:—

"I have also been surprised, considering the popularity of flying boats, that the Committee was not vigorously attacked for its sins of omission. . . . I thought then it was a mistake; I am sure of it now."

"And then the tragedy, how operators for the moment have forsaken them. It will not be thus for long. We await with anxiety the first flights and commercial use of the Princess."

Lord Brabazon supports the author of the book in his view that the really big aircraft of the future will be flying boats. Economic reasoning will dictate their return, and this is "the only thing that can move the hard headed operators."

Designers and scientists are already planning the introduction of really big aircraft. It has been suggested that jet propulsion will suffice until aircraft come nearer the 300-ton category, when another method of power must be found. Enough is known of nuclear energy today to realise that it will be the answer. There are those among us who will see atomic energy replacing the gas turbine. In the opinion of Mr. Henry Knowler, Chief Designer of Saunders-Roe Ltd., the first atomic-powered aircraft may well be a flying boat*:—

". . . for a reactor of a hundred tons, an aircraft of 200 to 300 tons would be necessary. This is a very big aircraft to contemplate as a landplane, but as a flying boat, such a size would be acceptable without query."

He also believes that because of runway and land limitations and cost, the big aircraft of tomorrow must be flying boats.

This generation may have cause to look forward with some joy to the application of atomic energy as a means of propulsion because, like the internal combustion engine, the turbo-jet depends on supplies of oil. I cannot guess how long the known and unknown oil resources of the world will last, but twice in a lifetime we have known the fight for oil. It would not be too sweeping a statement to say that the First and Second World Wars were won by the nations that controlled the major share.

Let us look at the revolution in transport which is taking place, to see what it means to mankind. One of the greatest benefits is that people of all nationalities are brought closer together. Commerce benefits by the quicker interchange of goods and ideas. Health benefits because speed has made possible the transfer of drugs which deteriorate if not transported and used quickly. Relief is brought quickly to victims of earthquakes, hurricanes and floods. Living standards of those in remote places are raised. Speed as a factor in human relations cannot be discounted.

It is difficult for even those engaged in the industry today to extend their thinking from passengers (39 million were carried by the world's scheduled airlines in 1951) to freight. In 1949 the freight carried by scheduled airlines exceeded that of 1948 by 25 per cent., while the 1950 figure exceeded 1949 by 33⅓ per cent. Figures for 1951 are not yet available, but it is safe to say that the increase will be comparable. Freight is even now showing the largest percentage increase of all the commodities carried by air, although it is more in its infancy than the carriage of passengers and mail, which today are looked upon as the life blood of commercial aviation. With larger and more economical aircraft, all but the bulkiest and heaviest of consignments could be carried by air.

With freight, speed means money. Ships have been saved costly hold-ups at remote ports by the swift carriage of spares; manufacturers can save royalties and insurance on expensive equipment hired by them; perishable goods can be brought fresh to the world's markets; film and television versions of important world events are screened in far away countries within hours of the events taking place. The time will come when cargo will be of prime importance, and passengers and mail secondary considerations.

One of the world's greatest problems is the unbalance of population, and the unequal distribution of goods. The need for migration has become a dire necessity, and governments are laying plans to cover the next 30 to 50 years.

The carriage of migrants by air has already started, but it will become a flood. The longer the solution of the problem is delayed, the more necessary will aviation assistance become. This factor alone will warrant governments having at their command fleets of large aircraft, capable of handling these movements expeditiously and economically. Speed has become a factor in modern life

*Fifth Louis Bleriot Lecture. *Journal R.Ae.S.*, May 1952.

which cannot be disregarded. It may be costly today, but not tomorrow, and airlines are able already to show that the all-in cost of moving masses of people from A to B is less by air. The whole approach of aircraft construction is towards lower operating cost.

Travel for the masses has always been the aim of airlines. A start has been made by the introduction of Tourist services, and with more economical aircraft the world will be within reach of the average man. The great majority of people enjoy only a fortnight to three weeks' holiday a year, and within a few years they will be able to spend this on the other side of the world.

The potential value of tourism as a revenue earner to those countries endowed with attractions above the average, and New Zealand is one, is established, but New Zealand has not yet come to a full realisation of its worth. Governments must realise that an ever-increasing outlay on publicity is necessary if the harvest is to be reaped. In 1951 the tourist industry earned the United Kingdom £104,000,000, from 700,000 foreign visitors. Approximately £25,000,000 of this was in hard currency. Canadian tourist revenue was about £100,000,000, while Australia earned £12,000,000. New Zealand's share was only about £1,500,000.

A tourist's tastes are simple and not very exacting. His money comes easily to us. What he requires most is good accommodation, good transport, a measure of entertainment, and above all a friendly reception and courteous treatment. New Zealand is not getting its fair share of this lucrative trade and needs an organisation similar to the British Travel Association.

What aviation, and hence speed, mean to the national economy are difficult to assess in terms of cash. A wool sample carried from New Zealand to the appraisers in Bradford in a few days may result in an order worth millions of pounds being placed here, instead of with a country closer at hand. In these days speed and time are vital to commerce, and a nation that encourages civil aviation will prosper.

If war should come

When considering Civil or Commercial Aviation, its defence significance must be taken into account for, in the words of Mr. Churchill, "For good or ill, air mastery is today the supreme expression of military power."

That governments are aware that Civil Aviation is supplementary to defence, is evident. A report of the Congressional Aviation Policy Board of the United States, contains the following statement:—

"Hence it is the conviction of the Congressional Policy Board that a strong, stable and modern Civil Aviation component is essential to air power for national security."

Air Chief Marshal the Hon. Sir Ralph Cochrane, Vice-Chief of Air Staff, R.A.F., and one time Chief of Air Staff, R.N.Z.A.F., has said that:—

"The overall requirements for aircraft added up to a considerable load on the available national resources. Very careful thought would have to be given before deciding not to meet them. Air power, if it is to be permanent, must be *broad based on commerce* and it must be wielded by an Air Force, in the building of which our first thought must be for quality, but if we are to meet the perils of the day, we need more rapid production. We must build up our industry immediately, because we must rearm, *but in the long term, because we ought to create a home and overseas trade comparable with our shipping industry.*"

Obviously Sir Ralph was more than hinting at the desirability of Britain creating an industry as great as the shipyards that have jammed the Clyde, the Tyne, the Mersey, Belfast Loch, and other important areas, for years.

There is no escaping the fact that Britain's greatness had maritime foundations, but change is upon us. Are we going to take advantage of the obvious lead the scientists and designers have given us?

The answer is in production, faster and more and more production. It has been suggested that some part of the motor and shipping industries should be sacrificed to achieve this end. One modern four-engined transport aircraft, with spares for eight to ten years, would represent exports to the value of one million pounds and it would take a lot of cars to equal that. Whereas practically every nation in the world that is in any way industrialised is making motor cars, the aircraft market for years to come is wide open. Britain has the knowledge and the brains to back it. Can she solve the production problem? On her ability to do this may well depend the future of the British Commonwealth of Nations.

To be an Air Power in the world, Britain must exploit her lead in the commercial field. Fighters and bombers alone will not make her one. The United States has already accepted Britain's challenge, but she is taking a different course to arrive at the same place. This race of friendly rivalry will be won by the nation best able to produce the goods. Britain's resources of men and materials are limited, she would be well advised to direct them into channels best calculated to serve the long-range future.

Is it out of place that we should be continuously giving advice to a struggling Britain? Should we not ask ourselves as a member nation of our great Commonwealth if we are doing our part? Powers are striving to achieve unity in the West, but should we not first look at ourselves and see if we have a family unity? I suggest the time has arrived vigorously to revive Commonwealth Civil Aviation planning. If such planning is to be of any use, member nations must come to the conference table in a spirit of unselfishness, prepared if necessary, to subordinate their own national aspirations for the common good of the Empire and the western world as a whole.

A war, if it should come, will be won or lost in the first few months. Victory will go to the combatants who first establish air supremacy and retain it. There will be no time for a game of bowls as in Drake's time.

With atom bombs, hydrogen bombs and all the other diabolical weapons now at the disposal of man, it is obvious that time at the start of a war will have to be measured in minutes and hours, not days, months and years. Unless absolute guarantees of peace can be arrived at by negotiation, there is only one alternative—instantaneous preparedness.

The Air Forces will be the first line of defence, but as a second line, "a strong, stable and modern Civil Aviation component is essential to national security."

Gone are the days when men and materials of war will be moved in enormous slow-moving ship convoys. Let us not forget the underwater menace, which is receiving the same amount of research today as high-altitude flying. Supremacy over underwater craft may be a slow job and more difficult to achieve than the attaining of air supremacy. In any case, control of the submarine depends to a large extent on aircraft and surface hunters being given freedom to move, which again means air supremacy.

As another war would probably include the whole world, world-wide communications at high speed must be maintained, and this is where the Merchant Air Force will fill its rightful role. Men and materials of war must be brought quickly from the ends of the earth, civilian needs must be catered for, commerce must continue, because economics call the tune as much in war as in peace, the mails must go through, and faster than ever. The very existence of our people will depend on speed.

With air supremacy established, speed and resort to the air will mean greater safety. If an aircraft is shot down, the lives risked would be no more than 100-200, compared with the result of a submarine sinking several 50,000-ton troopships, carrying, say, 10,000 troops each. A fleet of 100 aircraft of the type we should see within the next few years, will be capable of moving 10,000 troops across the world in two to three days, and it will be possible to move their equipment at the same rate.

Let us not forget too that Civil Aviation provides a nation with a reserve of manpower, highly skilled in the crafts that this mechanical age demands. It also establishes, for peaceful purposes, facilities which are of inestimable value in time of war.

Conclusion

At this stage, we might well ask ourselves, the rank and file of the industry, how we can assist our great cause. Hard work and maximum production is the answer, and I am not thinking in terms of 40-hour weeks or even the hours we put in, or what we put into the hours, but rather that if we fully appreciate the real purpose of our cause, and thereby have an intense interest in our work, be we planning, pushing a pen, or turning a spanner, then our efforts are not measured in terms of man-hours and piece-work rates, but more in what and how much our consciences tell us we contribute to the cause and ideal we serve. We live in remarkable times and future generations will be our judge and jury. It is up to us, in ushering in this revolution in transport in such a short time, to see to it that the foundations are well and truly laid.

REVIEWS

The following are reviewed:—

Air-plane Flight.
Automatic Feedback Control.
Aerodynamics of the Helicopter.
Hiduminium Technical Data.
Airplane Design Manual.
Ballistics in the Seventeenth Century.

AIR-PLANE FLIGHT. A. York-Bramble. Sir Isaac Pitman & Sons Ltd., London. 1952. 365 pp. 238 figures. 35s. net.

As Lord Brabazon says in the foreword, this book is "a veritable encyclopædia of aeronautical knowledge." The range of subjects covered certainly justifies the title of encyclopædia, but aeronautical knowledge is now so vast that, in a mere 365 pages, only a very elementary treatment is possible.

The author establishes, at the outset, the relationship of instructor and pupil pilot. The chapters are called "Flights," and, at the conclusion of each, a cross-examination and questions to the pupil seek to recapitulate the lessons of the "flight." The first half of the book explains, with the aid of a profusion of excellent diagrams, why the aeroplane flies. These figures range from a spring balance applying a moment to a fire-barred gate to a sectioned constant speed governor unit. Many of the simpler diagrams illustrate fundamental physical facts very clearly but some of the complicated ones are surely out of place in an elementary book, *e.g.* the geometrical constructions showing the Joukowsky transformation of a circle into an aerofoil.

In the second half of the book the author deals with the aids used by the pilot in using his aircraft—meteorology, instruments and blind flying, airfields, navigation, maintenance, etc. Here again the amount of detail is considerable (from a drawing of the forced landing emergency signal for "Send food and water" to the navigational advice to "use a *hard* pencil with a *sharp* point").

It would be unreasonable to expect to find no mistakes in a work of this scope. Errors are, however, more serious in an elementary book where the reader tends to be uncritical, than in an advanced treatise where readers are already experts in the subject and prepared to challenge any statement. To say with Mr. York Bramble that "lift always acts at *approximately* a right angle to drag" (reviewer's italics) is to weaken the pupil's understanding of one of the most elementary definitions. There is, too, serious confusion between mass-balancing and aerodynamic balancing of control surfaces (pp. 135, 140). Again, the discussion (on p. 130) of "engine torque reaction effect" is unnecessarily complicated. The simple fact is that, if an engine attached to the airframe applies a torque to the air (through a propeller, say), there will be an equal and opposite torque applied by the air to the aircraft. There is no need to explain it by the inclination of the piston connecting rods to the cylinder axis and then to say that the torque "is aggravated by the drag of the propeller blades." After reading this the pupil may think that the propeller driven by a gas turbine, having no connecting rod, will have no torque.

It must be remembered, however, that it is much easier to explain aeronautics in mathematical symbols than in words. The author has, with barely an equation to deter the pupil, succeeded in his aim of making "the picture intelligible and interesting to beginners."

AUTOMATIC FEEDBACK CONTROL. Ahrendt and Taplin. McGraw-Hill, New York. 412 pp. Diagrams. Bibliography. 64s. net.

This book which has taken over a year to arrive in this country is one of the first to emphasise the non-linear nature of control systems. Care has been taken to show the limits of usefulness of the linear analysis. The authors have a weight of practical experience which has enabled them to maintain a balance between general feedback control theory and particular industrial application. The nomenclature is consistent with the recommendations of the A.I.E.E. and A.S.M.E. and differs from British terminology. For this reason the symbols also seem strange, as for example the use of r and c for input and output functions (reference input and controlled variable).

The first six chapters contain the basic linear theory, including an introductory chapter and one solely devoted to mathematics. The fifth chapter deals with the characteristics of typical control loops and is rich in diagrams, including for example, the Nyquist plot, the Bode Open Loop Gain and Phase diagrams, the closed loop frequency response, the error frequency response and the error transient response to ramp and step function inputs for eight different systems. The diagrams for one system are all contained on one page for easy comparison. The sixth chapter is an outstanding account of multiple loop systems.

The remainder of the book deals with design considerations, together with an introduction to the non-linear aspect of control systems. Components and practical systems in the fields of pneumatic controllers, temperature regulators, speed governing and the control of pressure, flow and liquid level are also extensively discussed.

For the reader on his own the standard is probably post-graduate, although most of the chapters could be used at the undergraduate stage concurrently with a lecture course. The book will be useful to designers and research workers in the automatic control field. The latter will regret the exclusion of references in the text to advanced research papers, especially on the non-linear topics. Of particular interest to students is the fact that every portion is well illustrated and at the end, 254 problems with numerical answers on separate pages.

This is a book which speaks with authority developed from experience and is the type from which quotations will regularly be made.

AERODYNAMICS OF THE HELICOPTER. Gessow and Myers. MacMillans, New York. 1952. 340 pp. Diagrams. $6.00 net.

There has been a great need for a textbook presenting the aerodynamic theory of rotating wing aircraft clearly and simply, and the authors have succeeded admirably in meeting this need.

Both are working on helicopter problems in the Flight Research Division of the Langley Memorial Aeronautical Laboratory of the N.A.C.A., and quite naturally the book is based on the work done by the N.A.C.A. It is indeed a résumé of practically every report on rotating wing aircraft which has been published by the N.A.C.A., and to have given the essential material from all this work within the compass of 340 pages is deserving of the highest praise. Not only this, but the material is presented in a form understandable by the student, without recourse to any advanced mathematics, and a most valuable feature throughout the book is the great care which has been taken to give a physical explanation of the phenomena associated with rotating wings.

The first two chapters are a short history of the development of the helicopter, which is far from complete but serves to indicate general trends in the development, and a description of the mechanisms used, the various types of rotor and control systems, and the general flight characteristics of the helicopter. Then follow three chapters covering an introduction to hovering theory, the aerodynamics of hovering and vertical flight, and a discussion on the factors affecting vertical flight performance, *i.e.* blade thrust and taper solidity, top speed, and ground effect. These are followed by an excellent treatment of autorotation. Before passing on to the more complex analysis of the forces and moments on a rotor in forward flight, a complete and easily understandable account is given of the motion of articulated blades and of rotor control. Then, having given a physical explanation of flapping and its effects, the eighth chapter develops the aerodynamic theory of a rotor in forward flight, leading to a chapter dealing with the method of helicopter performance estimation given in N.A.C.A. Report ACR L4H07. This method is put forward as the most refined yet published, and one which accurately predicts performance. It is certainly refined, and simple to use, but one is a bit chary of accepting the claim for accuracy in prediction until more helicopters have been tested and their performance measured accurately, so that further checks can be made.

Throughout the chapters on theory and performance estimation the subject matter is presented logically and much more clearly than the original reports, on which the analysis is based. Every step in the analysis is fully explained and can be followed by the veriest tyro.

The final chapters give a complete description of how blade stalling occurs and its effect on high-speed flight, and a discussion on stability and vibration. In the chapters on stability and vibration no mathematical treatment is given but instead the fundamentals are clearly explained in physical terms.

Lastly there is a complete bibliography of N.A.C.A. papers on rotating wing aircraft, with a not so complete list of references from other sources.

Altogether this is a most welcome addition to the literature on the helicopter, and a book which should be in the hands of every student of the helicopter, and every engineer in the helicopter industry who wants to gain a thorough understanding of the aircraft on which he is engaged. The thanks of all concerned with helicopter development are due to Gessow and Myers for such a lucid and readable digest of the essential material available in the N.A.C.A. reports.

HIDUMINIUM TECHNICAL DATA. High Duty Alloys Ltd., Slough, Bucks. 1952. 125 pp. Diagrams and Tables.

Commercial publicity has often all too little relationship with ethics. The advertising of metallurgical products, however, has not greatly erred in this direction. Admittedly grossly inaccurate statements have sometimes been made. Alloys have been blatantly described as corrosion resistant, when in fact they are prone to that most insidious form of the disease, intercrystalline corrosion. For others, freedom from notch sensitivity has been claimed, but when this comprehensive statement has been objectively examined, it has been found to be based on experimental results derived from tests in which the notch, from the stress concentration point of view, was of quite exceptional gentleness.

Such undue economies in truth can seldom be cited against the companies producing aluminium alloys. In general, both in this country and in America, these have alike avoided the *suggestio falsi* and the *suppressio veri*, without in any degree hiding under a bushel the light of the good qualities of their products.

The publication of High Duty Alloys Ltd., now reviewed, is an excellent example of what technical publicity should be. This organisation, founded a generation ago by the late Colonel W. C. Devereux, has, from its very beginning, had a most well-deserved reputation for the high quality of its technical advertising. The Company makes some 28 aluminium alloys. Being a commercial undertaking and not a research institution, it not unnaturally wishes to sell them in the largest possible quantities.

With this entirely laudable end in view, it has issued an intriguingly bound book of some 125 pages. A little over 100 of these are devoted to giving in concise terms a wealth of technical information in relation to each of its products, while the remainder contain some entirely pertinent observations on mechanical properties, welding, anodizing, etc. Looking through these leaves one is somehow reminded of the between-the-wars dictum of a foreign cynic, to the effect that culture in England was mainly derived from studying the information contained on the backs of cigarette cards. Be this as it may, few will be able to read this unashamed advertising matter without adding considerably to their metallurgical knowledge of the aluminium alloys. The book can be strongly recommended to designers and to production engineers, for it is a mine of factual information likely to be useful to both, set out with conciseness and lucidity.

AIRPLANE DESIGN MANUAL. Frederick K. Teichmann. Pitman, New York. 1950. 382 pp. Illustrated. 55s. net. *Third Edition.*

The first edition of this book appeared in 1939. The present edition covers almost identically the same ground, with the addition of chapters on Types of Aeroplanes, Aerofoil Section, Control Systems and Materials of Construction, and a number of Appendices containing much useful reference data. The presentation of the matter is a considerable improvement on the old edition, and the book is made thereby very readable. Something—but not very much—is said about the problems of design for flight at transonic and supersonic speeds, including a brief review of the new forms of power propulsion.

As might be expected in a work attempting to cover such a wide field, the amount of detailed information under each heading tends to be inadequate. Nevertheless, on the whole, in view of the field it covers, it is a book well worth including in one's library.

Inadequacy of treatment seems to be particularly the case in the subject of weight estimation. It is doubtful whether the student, after reading the chapter dealing with this, will be in any better position to make a preliminary estimate of the weight of his project. Incidentally, a decimal point seems to be missing from the empirical formula for wing structure weight on p. 63, which, as it stands, gives a wing weight about 15 times the gross all-up weight of the aircraft. Four lines lower down "*w*" should read "*W*."

The inclusion of a chapter on aerofoil selection is an excellent idea. The simple aerodynamic characteristics required for various optimum flight conditions are developed for horizontal flight, gliding, climbing, etc. It is a pity, however, that when dealing with the question of Range (p. 36) the author just quotes what he describes as the "so-called Breguet formula," when he could have derived it so easily—to the greater satisfaction of the student.

One feels that in a book of this kind the student should be given some sort of simple explanation of why certain things are done. For example, on the matter of wing taper (p. 194), it seems that "it varies according to the whim of the designer." However much truth there may be in this, the student would be better enlightened if something were said about the way in which, for example, wing taper affects the aerodynamic characteristics of the wing. Again, the chapter on tail surface design makes no mention of "tail volume" or, alternatively, of the way in which the areas of these surfaces and their distances from the c.g. of the aeroplane are bound up with stability.

Nevertheless, to the student who wants a good general picture of the design problem before proceeding to a more rigorous study of the subject, the book is to be recommended.

BALLISTICS IN THE SEVENTEENTH CENTURY. A. R. Hall. Cambridge University Press. 1952. 186 pp. Illustrated. 21s. net.

This book is described in the sub-title as "A study in the relations of science and war with reference principally to England." It is a specialist study, written by a lecturer in the History of Science, and is a history of the inception and growth, practical and theoretical, of the knowledge of ballistics. The early methods of gunfounding, of powder-making and of artillery practice, and the stages of evolution of a mathematical theory of the flight of projectiles are described. The book will be particularly attractive to those interested in the history of science.

ADDITIONS TO THE LIBRARY

BOOKS

British Electrical Development Association. Materials Handling in Industry. B.E.D.A. 1952.
Burgess, E. Rocket Propulsion. Chapman & Hall. 1952.
Coulthard, W. H. Aircraft Instrument Design. Pitman. 1952.
Dunlop Rubber Co. Aviation Equipment Manual. 1952.
*Fontanet, G. L. Aviation—A Technical Dictionary (Eng.-Fr., Fr.-Eng.). Harrap. 1952.
Frazer, R. A. and C. Scrutton. A Summarised Account of the Severn Bridge Aerodynamic Investigation. N.P.L. 1952.
Gerard, G. Comparative Efficiency in Bending of Structural Elements of Various Designs and Solidity. U.S.O.N.R. 1952.
Hirsch, H. The Contribution of Higher Mode Resonance to Helicopter Rotor Blade Bending. I.Ae.S. (Preprint).
Iron & Steel Institute. High-Temperature Steels and Alloys for Gas Turbines. Special Report 43. 1952.
Janis, I. L. Air War and Emotional Stress. McGraw-Hill. 1952.
Love, R. J. The Fatigue Strength of Steels. M.I.R.A. 1950.
Manley, G. Climate and the British Scene. Collins. 1952.
National Physical Laboratory. Recent Developments and Techniques in the Maintenance of Standards. H.M.S.O. 1952.
O'Donnell, P. D. Production Control. Prentice-Hall. 1952.
Pankhurst, R. C. and D. W. Holder. Wind-Tunnel Technique. Pitman. 1952.
Postan, M. M. British War Production. H.M.S.O., Longmans Green. 1952.
Seely, F. B. and N. E. Ensign. Analytical Mechanics for Engineers. 4th edition. John Wiley. 1952.
Shaw, D. R. Notes on Backward Facing Seats. Australia; Dept. of Civil Aviation. 1952
Society of Automotive Engineers. U.S. and British Commonwealth of Nations Aircraft Metals. 1944.
Society of British Aircraft Constructors. Your Future in Aircraft Engineering. 1952.
Stieglitz, W. I. Cockpit Design and Safety. I.Ae.S. Preprint 381. 1952.
Stout, W. B. So Away I Went. Bobbs-Merrill Co. 1951.
Thielsch, H. Thermal Fatigue and Thermal Shock. Welding Research Council. 1952.

REPORTS

AERODYNAMICS

Boundary Layer

Experimental and theoretical studies of area suction for the control of the laminar boundary layer on an N.A.C.A. 64A010 airfoil. A. L. Braslow, D. L. Burrows, N. Tetervin and F. Visconti. N.A.C.A. Report 1025.
Investigation of separation of the turbulent boundary layer. G. B. Schubauer and P. S. Klebanoff. N.A.C.A. Report 1030.
A study of the stability of the laminar boundary layer as affected by changes in the boundary-layer thickness in regions of pressure gradient and flow through the surface. N. Tetervin and D. A. Levine. N.A.C.A. Technical Note 2752.

Compressible Flow

Velocity distribution on a family of thin conical bodies with zero incidence according to linearised supersonic flow theory. F. Hjelte. Royal Institute of Technology, Stockholm. T.N. 22.
A numerical integration method for calculating the pressure distribution at supersonic speeds for wings with subsonic leading edge at symmetrical flow conditions. V. V. Linnaluoto. S.A.A.B. T.N. 6.
The flat triangular wing with subsonic leading edges in steady pitch and roll at supersonic velocities. H. Behrbohm. S.A.A.B. T.N. 9.
The lifting trapezoidal wing with small aspect ratio at supersonic speed. H. Behrbohm. S.A.A.B. T.N. 10.
Ebene Plattengitter bei Uberschallgeschwindigkeit. R. M. El Badrawy. Zurich Report 19.
An analysis of base pressure at supersonic velocities and comparison with experiment. D. R. Chapman. N.A.C.A. Report 1051.
Supersonic flow with whirl and vorticity in axisymmetric channels. R. J. Eschborn. N.A.C.A. Technical Note 2768.

FLUID DYNAMICS

Efforts aérodynamiques sur un profil animé d'un mouvement quelconque dans un fluide en repos à l'infini. G. Couchet. O.N.E.R.A. Publication No. 56.

Die Stromung um schlanke, fast drehsymmetrische Korper. F. Riegels. Max-Planck-Institute, Gottingen. Report 5.

Experimental investigation of the effects of viscosity on the drag and base pressure of bodies of revolution at a Mach number of 1.5. D. R. Chapman and E. W. Perkins. N.A.C.A. Report 1036.

Spectra and diffusion in a round turbulent jet. S. Corrsin and M. S. Uberoi. N.A.C.A. Report 1040.

A study of effects of viscosity on flow over slender inclined bodies of revolution. H. J. Allen and E. W. Perkins. N.A.C.A. Report 1048.

INTERNAL FLOW

Wind-tunnel investigation of air inlet and outlet openings on a streamline body. J. V. Becker. N.A.C.A. Report 1038.

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STABILITY AND CONTROL

Experimental investigation of the effect of vertical-tail size and length and of fuselage shape and length on the static lateral stability characteristics of a model with 45° swept-back wing and tail surfaces. M. J. Queijo and W. D. Wolhart. N.A.C.A. Report 1049.

A summary of lateral-stability derivatives calculated for wing plan forms in supersonic flow. A. L. Jones and Alberta Alksne. N.A.C.A. Report 1052.

WINGS AND AEROFOILS

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Tests in the compressed air tunnel on the aerofoils N.A.C.A. 0015 and N.A.C.A. 0030 with and without split flap and on other aerofoils of various thicknesses with a split flap. R. Jones. A.R.C. R. & M. 2584.

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Effects of Mach number variation between 0.07 and 0.34 and Reynolds number variation between 0.97×10^6 and 8.10×10^6 on the maximum lift coefficient of a wing of N.A.C.A. 64-210 airfoil sections. J. E. Fitzpatrick and W. C. Schneider. N.A.C.A. Technical Note 2753.

AEROELASTICITY

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AIRCRAFT OPERATION

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Experiments in external noise reduction of a small pusher-type amphibian airplane. J. P. Roberts and L. L. Beranek. N.A.C.A. Technical Note 2727.

Experimental studies of noise from subsonic jets in still air. L. W. Lassiter and H. H. Hubbard. N.A.C.A. Technical Note 2757.

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The effect of surface active agents on petroleum fuels. F. G. Kitson. N.A.E. Canada. Note 8.

Carbon formation in flames of aromatic hydrocarbons by W. Sacks and M. T. I. Ziebell. N.A.E. Canada, Laboratory Report 30.

General method and thermodynamic tables for computation of equilibrium composition and temperature of chemical reactions. V. N. Huff, S. Gordon and Virginia E. Morrell. N.A.C.A. Report 1037.

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INSTRUMENTS AND EQUIPMENT

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MATERIALS

The effect of decarburization and other factors on the fatigue strength of roll-threaded aircraft bolts. I. Weibull. S.A.A.B. T.N. 4.

Wear and sliding friction properties of nickel alloys suited for cages of high-temperature rolling-contact bearings. I—Alloys retaining mechanical properties to 600°*F. R. L. Johnson, M. A. Swikert and E. E. Bisson. N.A.C.A. Technical Note* 2758. *II—Alloys retaining mechanical properties above* 600°*F. R. L. Johnson, M. A. Swikert and E. E. Bisson. N.A.C.A. Technical Note* 2759.

PHYSICS

Chronophotographie des vibrations d'un fluide. J. M. Bourot. Publications Scientifiques et Techniques du Ministère de L'Air, France. No. 264.

Contribution a l'étude du coéfficient de viscosité des liquides. J. Huetz. Publications Scientifiques et Techniques du Ministère de L'Air, France. No. 260.

POWER PLANTS

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Theoretical investigation of velocity diagrams of a single-stage turbine for a turbojet engine at maximum thrust per square foot turbine frontal area. L. Cohen. N.A.C.A. Technical Note 2732.

REFERENCE LITERATURE

Actes du Colloque International de Mécanique. Poitiers 1950. *Tome V. Etudes sur la mécanique générale (Suite). Publications Scientifiques et Techniques du Ministère de L'Air, France. No.* 263.

STRUCTURES

Theory and Analysis

The compressive buckling of a clamped parallelogram plate with a longitudinal stiffener along the centre line. J. Guest. A.R.L. Australia. Report S.M. 194.

Strains and rib deformations, measured near the root of a 45° *swept rectangular tube. J. E. Wheeler and N. B. Joyce. A.R.L. Australia. Structures and Materials Note* 197.

Application of electric-resistance strain gauges to strain-measurement in ply-wood faces of sandwich panels. J. Solvey and G. L. Belcher. A. R. L. Australia. Structures and Materials Note 198.

Structural analysis of swept-back wings by matrix-transformation. B. Langefors. S.A.A.B., Sweden. T.N. 3.

An empirical formula for the ultimate shear strength of wing leading edges. F. Turner. S.A.A.B., Sweden. T.N. 5.

Buckling of thin-walled cylinder under axial compression and internal pressure. Hsu Lo, H. Crate and E. B. Schwartz. N.A.C.A. Report 1027.

A biharmonic relaxation method for calculating thermal stress in cooled irregular cylinders. A. G. Holms. N.A.C.A. Report 1059.

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